Effects of Different Coho Stocking Strategies on Coho and Cutthroat Trout Production in Isolated Headwater Streams

D. Tripp and P. McCart

Salmonid Enhancement Program
Department of Fisheries and Oceans
1090 Pender St.
Vancouver, B.C. V6E 2P1

Canadian Technical Report
of Fisheries and Aquatic Sciences
No. 1212

Canadian Technical Report of Fisheries and Aquatic Sciences

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Canadian Technical Report of

Fisheries and Aquatic Sciences 1212

August 1983

EFFECTS OF DIFFERENT COHO STOCKING STRATEGIES ON COHO AND CUTTHROAT TROUT PRODUCTION IN ISOLATED HEADWATER STREAMS

Prepared For

Department of Fisheries and Oceans
And
Ministry of the Environment
BC Fish and Wildlife Branch

By

P. McCart Biological Consultants Ltd.
D. Tripp and P. McCart

Salmonid Enhancement Program
Department of Fisheries and Oceans
1090 West Pender Street
Vancouver, B.C. V6E 2P1

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Cat. No. FS 97-6/1212 ISSN 0706-6457

Correct citation for this publication:

Tripp, D. and McCart, P. 1983. Effects of Different Coho Stocking Strategies on Coho and Cutthroat Trout Production in Isolated Headwater Streams. CAN. Tech. Rep. Fish. Aquat. Sci. 1212: xi + 176 p.

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ABSTRACT

Tripp, D. and McCart, P. 1983. Effects of Different Coho Stocking Strategies on Coho and Cutthroat Trout Production in Isolated Headwater Streams. CAN. Tech. Rep. Fish. Aquat. Sci.1212: xi + 176 p.

In 1980, groups of hatchery reared coho salmon (Oncorhynchus kisutch) fry were released above impassable falls in two streams, Banon Creek and Bush Creek, draining the east coast of Vancouver Island, British Columbia. At the time of the release, the streams upstream of the falls were inhabited by a single species of fish, the cutthroat trout (Salmo clarki).

The major objectives of the study were: first, to evaluate the effects of different stocking times and densities on coho salmon growth and survival; second, to evaluate the effects of different stream types and variations in cutthroat trout densities on coho salmon growth and survival; and third, to evaluate the effects of various stocking strategies involving coho salmon on cutthroat trout production.

In both streams, coho survival (smolts produced as a percentage of initial stocking) tended to be highest when coho fry were stocked at low rather than high values and late rather than early in the year. In contrast, smolt production (smolts produced per unit stream area) was greatest at high rather than low stocking densities. At low densities, early stocking produced more smolts than late stocking, but the reverse was true at high initial stocking densities.

Growth of coho fry was greatest for fish stocked at the lowest densities early in the year. Growth appeared to be density dependent during the first (summer) growing season. During the second (spring) growing season, when most of the growth occurred, it appeared to be density dependent in Bush Creek, but less so in Banon Creek.

Net production (g/m^2) of coho fry tended to be greatest for coho fry stocked early in the year at high densities. Efficiency of production was also highest for early stockings, but at low rather than high densities.

Cutthroat trout populations, both young-of-the-year and older fish, were adversely affected by the stocking of coho fry. The effects, which included reduced survival, growth, and production, appeared to be greater in Bush Creek than in Banon Creek.

The report includes a discussion of how the results of the study can be used in planning stocking strategies for future transplants of coho fry into similar inaccessible streams.

RÉSUMÉ

Tripp, D. and McCart, P. 1983. Effects of Different Coho Stocking Strategies on Coho and Cutthroat Trout Production in Isolated Headwater Streams. CAN. Tech. Rep. Fish. Aquat. Sci.1212: xi + 176 p.

En 1980, nous avons relâché des groupes d'alevins de saumon coho (Oncorhynchus kisutch) d'élevage en amont de chutes infranchissables de deux cours d'eau, les ruisseaux Banon et Bush, situés sur la côte est de l'île Vancouver (Colombie-Britannique). Au moment de la mise en liberté, la partie des cours d'eau en amont des chutes était peuplée par une seule espèce de poisson, la truite fardée (Salmo clarki).

Les buts principaux de l'étude étaient les suivants: premièrement, évaluer l'incidence des différentes périodes et densités d'ensemencement sur la croissance et la survie du saumon coho; deuxièmement, évaluer l'incidence des différents types de cours d'eau et des variations de la densité de la truite fardée sur la croissance et la survie du saumon coho; et, finalement, évaluer l'incidence de diverses stratégies d'ensemencement du saumon coho sur la production de truite fardée.

Dans les deux cours d'eau, la survie des cohos (c.-à-d. le pourcentage de saumoneaux produits par rapport au nombre ensemencé) était plus élevée quand la densité des alevins ensemencés était faible et que l'ensemencement était effectué vers la fin de l'année plutôt qu'au début. Par contre, la production de saumoneaux (le nombre de saumoneaux produits par aire élémentaire) était à son maximum quand la densité d'ensemencement était élevée. À de faibles densités, un ensemencement hâtif a donné plus de saumonneaux qu'un ensemencement tardif, mais le contraire s'est aussi produit à des densités initiales élevées.

La croissance des alevins cohos était plus importante chez les poissons ensemencés aux plus faibles densités, au début de l'année. Elle semblait être reliée à la densité pendant la première saison de croissance (été). Au cours de la seconde saison (printemps), quand la plus grande partie de la croissance s'est effectuée, elle paraissait dépendre de la densité dans le ruisseau Bush mais non dans le ruisseau Banon.

La production nette (g/m²) d'alevins cohos tendait à être plus élevée chez ceux ensemencés au début de l'année, à de fortes densités. L'efficacité de la production était aussi plus importante pour les ensemencements hâtifs mais à de faibles densités.

L'ensemencement d'alevins cohos a influé négativement sur les populations de truite fardée, les jeunes de l'année comme les poissons plus âgés. Les effets, dont une baisse de la survie, de la croissance et de la production, semblaient être plus prononcés dans le ruisseau Bush que dans le ruisseau Banon.

Le présent rapport expose comment utiliser les résultats de l'étude pour élaborer des stratégies d'ensemencement d'alevins cohos dans de semblables cours d'eau inaccessibles.

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1.0 INTRODUCTION

In coastal British Columbia, many streams with areas suitable for rearing coho salmon (Oncorhynchus kisutch) occur upstream of impassable falls. Stocking such areas with young coho fry could materially increase the overall production of coho smolts in a drainage--in some instances, at relatively low cost and minimal risk to wild stocks (Parkinson and Slaney 1975).

Although constructing fishways or removing barriers by blasting might accomplish the same increase, by providing access to unused spawning and rearing areas, the high cost of these operations usually restricts their use to larger streams where more than one species would benefit and the number of additional smolts produced would be high. Fishway construction or barrier removal operations are generally too expensive for small streams, especially if the streams have relatively short sections of suitable habitat separated by more than one major barrier. Moreover, though sufficient rearing area may be present upstream, suitable spawning area may be limited.

Coho fry for headwater stocking programs can be derived from a variety of sources. Drainages which currently lack coho salmon because of a barrier near the sea could be stocked with surplus hatchery fry with little fear of spreading disease or contaminating the genetic integrity of existing stocks elsewhere. The inaccessible reaches of drainages where coho salmon are present could be stocked with newly emerged fry that have been displaced seaward from the lower reaches of the same drainage (Chapman 1962, Mason and Chapman 1965), fry that have been salvaged from intermittent tributary streams, sloughs, and sidechannels, or the surplus progeny of adult coho whose production of fry is be in excess of the rearing capacity of the accessible portion of a stream. Where disease and genetic contamination are not considered to be problems, the excess production of hatcheries could be used to stock inaccessible headwaters.

The success of headwater fry stocking programs depends in large part on determining how many coho smolts an isolated segment could produce and the most cost-effective method of achieving this production. First, however, the effects of stocking times, stocking densities, stream types, and the presence of other salmonids on coho survival must be adequately assessed. In addition, there is some concern over the possible effects of coho stocking programs on other salmonids such as steelhead trout (Salmo gairdneri), itself a likely candidate for stocking headwater streams, or cutthroat trout (Salmo clarki) and Dolly Varden (Salvelinus malma), both frequent inhabitants of headwater streams. If the effects of coho salmon on cutthroat trout are as serious as those anticipated by Glova (1978a), enhancement strategies which involve stocking coho on a regular basis in headwater streams may, in time, have a serious impact on isolated cutthroat trout populations.

In the present study, surplus coho salmon fry from the Big Qualicum River hatchery were stocked at different times and densities in two small Vancouver Island streams inhabited by isolated populations of cutthroat trout. One stream was unproductive, with relatively low densities or cutthroat trout; the other was much more productive, with relatively high densities of cutthroat trout. The major objectives of the study were:

1. To evaluate the effects of different stocking times and densities on coho salmon growth and survival;
2. To evaluate the effects of different stream types and cutthroat trout densities on coho salmon growth and survival; and
3. To evaluate the effects of various stocking strategies, involving coho salmon, on cutthroat trout production.

The study period extended from June 1980 to July 1981.

2.0 THE STUDY AREA

Banon Creek (Figure 1) and Bush Creek (Figure 2) are two small streams south of Nanaimo on the east side of Vancouver Island, British Columbia. These streams were chosen for this study because they were small enough to be effectively sampled, yet large enough to have isolated populations of cutthroat trout above impassable falls. Above the falls, each stream is characterized by at least 2 km of stream with a fairly constant gradient, a uniform distribution of microhabitats, a relatively stable drainage basin unlikely to be disturbed during the course of the study, and easy access by vehicle.

Both streams drain an area described by Krajina (1965) as Mediterranean Subhumid—a rainy climate with warm temperatures and a discrete dry season. Approximately 75% of the area's 75 to 100 cm annual precipitation occurs between October and March. As a result, stream flow is very low and quite stable during summer, but high with frequent fluctuations during fall, winter, and spring. In Bush Creek, recorded stream flows ranged from low or zero flow in August and September to a peak of 2.60 m^3/s in early November; in Banon Creek they ranged from 0.06 m^3/s in early August to 6.81 m^3/s in early November.

Banon Creek, a tributary of the lower Chemainus River, is the larger of the two streams with a total watershed area of 35 km^2. It flows for 23 km, declining 1000 m in elevation, before plunging over several sets of 5 to 10 m high falls located at its mouth. All of these falls are impassable and, as a result, anadromous salmonids are absent from Banon Creek. Only cutthroat trout and a small number of three-spined sticklebacks (Gasterosteus aculeatus) occur upstream. Two dams, one on the lower reaches and one on the upper reaches of Banon Creek, further impede the upstream movement of fish.

On Banon Creek, the study area encompassed the first 2.4 km upstream of the reservoir formed by the first dam (Figure 1). During the summer, stream width in this area averaged 7.4 m, channel width 13.2 m, and gradient 2.1%. In general, pool-to-riffle ratios are balanced, and fallen trees, upturned roots, log jams, and overhanging banks are common types of fish cover. The substrate is largely gravel, rubble, and boulders, providing excellent cover for juvenile salmonids; however, the presence of braided channels, extensive gravel bars, and recent log jams indicate that the substrate in Banon Creek is unstable and likely to shift considerably during heavy freshets. Streamside vegetation is primarily a mixture of alder (Alnus rubra), western hemlock (Tsuga heterophylla) and broad-leaf maple (Acer macrophyllum) with a diverse understory of red cedar (Thuja plicata), salal (Gautheria shallon), salmonberry (Rubus spectabilis), sword fern (Polystichum munitum), and stink currant (Ribes bracteosum).

Bush Creek has a drainage area of 23 km^2 and flows for 18 km at an overall gradient of 3.1% before entering the sea at Ladysmith Harbour. Bush Creek has three sets of impassable falls along its length, restricting coho salmon and sculpins to the lowermost 2.0 km of the stream. Only cutthroat trout occur upstream. The stream segment chosen for this study was 2.1 km in length and was located between the first and third set of falls (Figure 2).

In the Bush Creek study area, cover, pool-to-riffle ratios, and streamside vegetation were similar to those of Banon Creek. Unlike Banon Creek, however, the substrate in Bush Creek appeared to be more irregular than the substrate in Banon Creek and less inclined to shift during heavy freshets. Average stream and channel widths in the Bush Creek study area were 4.4 and 9.1 m, respectively. The gradient was 1.9%.

3.0 MATERIALS AND METHODS

3.1 Physical Parameters

From 11 June to 6 November 1980, and 9 March to 6 July 1982, water temperatures were measured regularly at the lower end of both study areas with Taylor maximum/minimum thermometers; dissolved oxygen concentrations were measured with a Hach dissolved oxygen kit (Model OX-10); and conductivity was measured with a Beckman conductivity meter (Model RA-2A). Water velocities for stream discharge measurements were also recorded during this period over a range of water levels with a recently calibrated Gurley Pygmy Current Meter. The discharge measurements were then compared to water depth readings on staff gauges to give stage height-discharge relationships. Discharge data were derived from daily stage height readings according to the following formulae:

1. Banon Creek

   $\log_{10}$ Discharge(m^3/s)=3.20 Stage Height(cm)-5.20

   ($N=8$, Range 0.01-6.81 m^3/s, $r=0.994$, $p<0.05$)

2. Bush Creek

   $\log_{10}$ Discharge(m^3/s)=1.29 Stage Height(cm)-1.90

   ($N=7$, Range 0.00-2.60 m^3/s, $r=0.933$, $p<0.05$)

Additional information on physical characteristics was collected during habitat surveys of Bush and Banon creeks, 22 to 25 September 1980. Throughout the length of both study reaches, at transects located at 20 m intervals, wetted width and rooted width were measured to the nearest 0.1 m. Water depth (to the nearest 0.01 m) and current speed (to the nearest 0.01 m/s) were also measured at each transect at either three or five equally spaced points, the number of points depending on the width of the stream.

Stream substrates were visually categorized and recorded as percent sand/silt, gravel, rubble, boulder, and bedrock (Lagler 1956). Filamentous algae and moss growing on the substrate were recorded as "lacking", "little", "occasional", "frequent", or "well developed". Fish cover was identified along a 1 m wide strip centred on each transect and recorded as percent occurrence without regard to the type of cover (e.g. upturned roots, overhanging brush, debris, undercut banks, logs, coarse rubble and boulder substrates). The length of eroded or falling banks (both sides) was recorded as a percentage of the total length of stream between transects (20 m); gradient was measured with an Abney Hand Level as percent rise in water level between transects.

A model developed by Binns and Eiserman (1979) was used to provide an objective evaluation of the salmonid habitat in each section of the two study streams. This was done, first, to determine whether any of the sections with each study stream was unusual in its potential productivity, and second, to provide an overall comparison of the fish habitat in the two streams.

Binns and Eiserman's model uses nine stream habitat attributes to predict fish standing crop in streams. These attributes include late summer streamflow, annual streamflow variation, maximum summer water temperature, nitrate nitrogen concentration, cover, eroding stream banks, substrate vegetation, water velocity, and stream width. With the exceptions of annual stream flow variation and nitrate nitrogen concentrations, all of these attributes are described in Figures 3 and 4 and Tables 1 and 2. Annual stream flow variation was estimated by comparing the lowest and highest flow rates recorded during the study and by examining the banks for high water marks and silt deposits. Nitrate nitrogen concentrations were determined in replicate water samples taken between 22 and 25 September 1980; and, using standard methods of analysis (APHA 1971), were found to range from 0.10 to 0.14 mg/L in both streams.

For each stream section, the above stream attributes were ranked on a scale of 0 (worst) to 4 (best) using the characteristics described in Table 3 (from Binns and Eiserman 1979) to rate each attribute. The resulting values were then used to predict fish standing crop according to the following formula:

$$\begin{aligned}\log_{10}(\hat{Y}+1) = [&(-0.903) + (0.807)\log_{10}(X_1+1)\\ &+(0.877)\log_{10}(X_2+1)\\ &+(1.233)\log_{10}(X_3+1)\\ &+(0.631)\log_{10}(F+1)\\ &+(0.182)\log_{10}(S+1)][1.12085]\end{aligned}$$

where $\hat{Y}$ = Predicted standing crop in kg/ha
X_1 = Late summer streamflow
X_2 = Annual streamflow variation
X_3 = Maximum summer stream temperature
F = Food index = $X_3(X_4)(X_7)(X_8)$
S = Shelter index = $X_5(X_6)(X_9)$
X_4 = Nitrate nitrogen
X_5 = Cover
X_6 = Eroding stream banks
X_7 = Substrate
X_8 = Water velocity
X_9 = Stream width

Predicted standing crop in kg/ha was converted by to g/m^2 by multiplying $\hat{Y}$ by 0.1.

3.2 Experimental Design

Each of the stream segments selected for study on Bush Creek and Banon Creek was divided into 10 sections of approximately equal length. Coho salmon fry were then stocked in the first nine sections of each stream at three different times of the year (mid July, late August, early October), each time at three different densities (0.5, 1.5, and 2.5 g coho fry/m^2). Numbering upstream, Sections 1 to 3 were stocked from 19 to 21 July; Sections 4 to 6 on 30 August; and Sections 7 to 9 on 8 October. Sections 1, 4, and 7 were stocked with 0.5 g coho/m^2; Sections 2, 5, and 8 with 1.5 g coho/m^2; and Sections 3, 6, and 9 with 2.5 g coho/m^2. As a further variation, coho fry were released throughout the length of each section stocked on Bush Creek (scatter plants), but only into the uppermost pool of each section on Banon Creek (point plants). The 10th and uppermost section in each stream acted as a control section containing only cutthroat trout.

In this study, the natural biomass of coho fry in nearby streams with sympatric populations of cutthroat trout provided the basis for coho fry stocking densities. During low flow periods in Bush, Holland, and Ayum creeks, this biomass was 1.5 g coho fry/m^2 (data from Glova 1978b; Text Table 3 and Appendix Tables 3, 4, and 5). The upper and lower limits of 2.5 and 0.5 g coho/m^2 were considered sufficient to show the effects of different stocking densities on coho salmon and cutthroat trout production.

Table 4 is a summary of coho stocking times and stocking densities in each of the experimental sections in Banon and Bush creeks. The initial densities shown were those based on the stream areas measured within individual sections at the time of stocking. The densities used as a basis for comparing survival and production in different sections, however, were those based on the stream areas within individual sections at low flow from 22 to 25 September 1980. As shown, the two values sometimes differed considerably as a result of variations in the morphology of different stream sections and their response to changes in the hydrological regime.

3.3 Source of Coho Fry

Coho fry were obtained from the Big Qualicum River hatchery. The July fish (mean fork length 49.9 mm, mean weight 1.4 g, N=25) were surplus coho fry held in a settling basin at the upper end of the spawning channel and fed at approximately one half the rate recommended for normal production fry. The August fish were also surplus fry from the same pool, but these fry had not been fed on a regular basis since July. As a result, a large proportion of the surviving fish were emaciated, and fish suitable for stocking had to be carefully selected. Average fork length of the fish selected from this group (N=43) was 57.2 mm; average weight was 1.8 g. The October fish were normal production fry from the hatchery's rearing channels. These fry (N=50) averaged 85.6 mm in fork length and 7.8 g in weight.

Coho fry stocked in July were not fin clipped; those stocked in August were marked by removal of the right pelvic fin; those stocked in October were marked by removal of the left pelvic fin. Each coho was also sprayed with granules of either red, green, or orange fluorescent pigment (Scientific Marking Materials, Seattle, Washington) to indicate the density at which fish were stocked. The methods used to mark fish with fluorescent pigment were similar to those described by Phinney et al. (1967). A more uniform particle size was achieved by using only those particles which passed through a 300 µm sieve. The pigment was then sprayed on fish with a sand-blasting gun from a distance of 30 cm at a pressure of 550 KPa. Air pressure was supplied by SCUBA tanks with an Aqualung Conshelf XIV regulator. During spraying, fish were restrained between two hinged frames covered with a coarse rubber mesh. To identify the colour of the fluorescent pigment present on fish in the field, a portable ultra-violet light source (Blak-Ray, Model ML-49) was used.

Coho fry were held for 24 hours after being fin clipped and sprayed. They were then trucked to the study streams in oxygenated plastic bags. Water temperature was controlled by packing ice around the bags. At the study streams, fish were transferred into buckets with a dipnet, and released into the appropriate experimental section.

3.4 Fish Movements

Temporary weir and trap facilities were placed at the upper and lower ends of each experimental section to monitor coho salmon and cutthroat trout movements during the first 20 to 30 days after stocking. During operation, each trap was checked daily and the essential data (species, fork length, fin clips, fluorescent marks) recorded for each fish captured. Cutthroat trout were released unharmed in their direction of travel; coho fry were retained to prevent them from mixing with the coho fry stocked in other sections.

The trapping operations ceased with the first major freshet on 1 November 1981. The following spring, new traps were installed at the lower end of each study area. The traps were checked at least once a day for emigrant coho smolts—from 9 March to 11 June 1981 in Bush Creek, and from 9 March to 23 June 1981 in Banon Creek. As before, cutthroat trout taken by the traps were measured to the nearest mm fork length and released unharmed. Coho smolts were retained and measured and weighed in the laboratory. The presence or absence of right or left pelvic fin clips was recorded to determine when each coho was stocked, and the colour of fluorescent pigment was used to determine the original stocking density. Caudal fin clips were noted for the Petersen mark-recapture estimates described below.

Weir and trap designs were similar to those described by Conlin and Tutty (1979). Separate panels measuring 2.4 m x 0.8 m were covered with 6.4 mm galvanized wire mesh and nailed together into V-shaped patterns that completely blocked the stream and guided fish into holding traps. Wire mesh stapled over the gaps between weir sections and traps reduced the chances of fish escaping through seams in the weir; an apron of wire mesh stapled to the bottom of the weir and dug into the substrate prevented fish from moving under the weir. The entire structure was anchored to the stream bottom with steel rods driven into the substrate. Ropes tied from the tops of the steel rods to nearby trees provided additional support.

Fish migrating downstream in the spring were directed by the weir to an adjustable 5 m long sluice trough and a baffled live box (Argue and Armstrong 1979). All other traps were simple box-like structures attached directly to the weir. Fine mesh seine material covered the sides and back of each trap. Floors, lids, and V-shaped entrances were constructed of plywood. Rocks placed in the bottom of each trap provided protection from the currents.

3.5 Population Estimates

A total of 51 population estimates was made in each of the two study streams, using a survey-removal method (Seber 1973). From 25 June to 31 October 1980, these estimates included:

1. Monthly estimates of cutthroat trout numbers in the control sections;
2. Estimates of the number of cutthroat trout present in the experimental sections before they were stocked with coho salmon; and
3. Monthly estimates of the number of cutthroat trout and coho salmon present in the experimental sections after they were stocked with coho salmon.

Additional estimates were made for both species in each section in March 1981, and for cutthroat trout in late June to early July 1981, after coho had left the two study streams. The details of the sampling schedule are summarized in Tables 5 and 6.

Each survey-removal estimate was conducted in the following manner. Three 30 m long census sites were established at the lower, middle, and upper end of each section and enclosed with fine mesh (6 mm mesh stretch measure) minnow seines. The enclosed sites were then systematically sampled with electroshockers and minnow seines at least three times, until the number of fish taken in the last catch was zero, or nearly so. Estimates of the number of coho salmon and/or cutthroat trout in each census site were then calculated according to Zipplin (1956, 1958). Estimates of the total number of salmon and trout in the entire section were obtained by multiplying the average number of fish in the three census sites ($\pm$2SD) by a factor: total section length divided by census site length.

A Petersen mark-recapture census was also used to estimate the number of coho salmon present in March 1981, because it was felt that the survey-removal estimates made at this time almost certainly underestimated the true number of fish present. The high water levels and low conductivities in March sharply reduced electrofishing efficiency and many of the fish overwintering in deep pools were probably missed. Every coho captured in March was marked by removing a small portion of the lower lobe of the caudal fin after the fish had been examined for pelvic fin clips and fluorescent dyes. Recaptures were recorded at the downstream smolt traps on each stream and the total number of coho originally present in March estimated for each stocking period and each stocking density using the following equation (Bailey 1951):

$$\hat{N} = \frac{M(C+1)}{R+1}$$

where M = the number of coho salmon clipped and released in March

C = the number of coho smolts trapped moving downstream

R = the number of clipped smolts recaptured

$\hat{N}$ = the estimated number of coho originally present in March

Confidence limits at the 95% confidence level were determined by treating R as a Poisson variable, obtaining limits for R from a table in Ricker (1975, Appendix II), and substituting these in the above formula.

The smolts traps are thought to have captured virtually all of the juvenile coho migrating downstream during the trapping period. With the exception of two high water periods on 5 and 23 April in Banon Creek, both smolt traps completely blocked off the lower ends of each study reach. There were no washouts during the downstream movements of coho smolts nor any evidence of vandalism or predation.

Instantaneous mortality rates (Z) were calculated according to Chapman (1971) as follows:

$$Z = \frac{-(\log_e N_2 - \log_e N_1)}{\Delta t}$$

where N_1 = the number of fish present in each section at t_1

N_2 = the number of fish present in each section at t_2

Assuming that all sampling occurred on the same dates, times t were 20 July, 30 August, 8 October, and 30 October in 1980, and 1 March and 10 June in 1981. Population numbers at these times for each group of coho salmon in the experimental sections and each age class of cutthroat in both experimental control sections were determined graphically in most cases from straight line interpolations between the actual population estimates. Where there was enough information, a smooth curve was drawn between the actual population estimates.

3.6 Age and Growth

During each sampling period, mean fork length (to the nearest mm) and mean weight (to the nearest 0.1 g) were determined for each year class of cutthroat trout in the experimental and control sections, and for each group of coho salmon in the experimental sections. All measurements were taken from individual fish that had been lightly anesthetized with MS-222 and patted dry before weighing. Fork length was determined using a plastic millimetre scale, and weight using a triple-beam balance. For cutthroat trout fry less than 0.3 g in weight, batch weights were recorded.

Scales were removed from subsamples of cutthroat trout not obviously young-of-the-year in August and October 1980 and in June 1981. The resulting scale-based age-length relationships were then used to assign ages to trout which were not aged directly at these or other times in July and September 1980 and March 1981. Assuming 50% mortality between age classes, two-thirds of the fish which fell where the mean ±2SD of one age class overlapped with the mean ±2SD of an adjacent age class were randomly selected and assigned the lower age. The remaining third was assigned the higher age.

Instantaneous growth rates in terms of weight increase (Gw) were calculated for coho salmon and each age class of cutthroat trout in each section using:

$$Gw = \frac{\log_e w_2 - \log_e w_1}{\Delta t}$$

where w_1 = average weight of individual fish at time t_1

w_2 = average weight of individual fish at time t_2

In the same way that population numbers were determined, average weight of individual fish on the same date in each section was determined with a straight line interpolation between adjacent point estimates.

A condition factor K (Everhart et al. 1975) was also used to compare the general well-being of coho salmon and cutthroat trout at each sampling period using:

$$K = \frac{W(10^5)}{L^3}$$

where W = the average weight (g) of the fish

L = the average fork length (mm) of the fish

The factor 10^5 brings the value of K near unity.

3.7 Production

The net production of coho salmon and young-of-the-year cutthroat trout between sampling periods in each section of the two study streams was calculated as the product of the average biomass and the instantaneous growth rate (Gw). Average biomass represented the arithmetic mean of biomass at the beginning and end of each sampling period. Biomass at the beginning of each sampling period was the product of the number of coho or young-of-the-year cutthroat trout present and the average weight of the coho salmon or young-of-the-year trout present.

The net production of the older age classes of cutthroat trout was calculated in a similar manner, except that they were considered as one group. Instantaneous growth rates (Gw) were calculated for each age class and then averaged to yield a representative growth rate ($\bar{G}$w) for older fish as a whole. Average weight of older cutthroat trout in each section was the sum of the products of average weight for each age class and the estimated number of fish in each age class, divided by the total number of fish in all age classes. Biomass at the beginning of each sampling period was then the product of the average weight of older trout and their average growth rate.

4.0 RESULTS AND DISCUSSION

4.1 Physical Data

4.1.1 Discharge and Water Quality

Data describing seasonal variation in discharge, maximum and minimum water temperatures, dissolved oxygen, and conductivity in the two study streams are presented in Figures 3 and 4.

In Banon Creek, in 1981, the mean weekly discharge in early June at the beginning of the study was 1.9 m^3/s, declining thereafter to a relatively low base flow that fluctuated between 0.1 and 0.2 m^3/s from late July through to the end of October. This base flow is maintained by controlling release of water from a regulated lake in the stream's headwaters and is required to provide an adequate supply of domestic water to the town of Chemainus. In early November, as the study ended for the year, heavy rains caused a rapid increase in discharge to an average weekly value of 3.7 m^3/s with an individual daily high of 6.8 m^3/s. In 1981, discharges declined until mid-March, increased to a peak in April, then declined again through early July when the study ended. Discharge during the first two weeks of July was slightly greater in 1980 (weekly averages of 0.67 and 0.38 m^3/s respectively) than in 1981 (0.31 and 0.26 m^3/s respectively).

Unlike Banon Creek, discharges in Bush Creek are natural and unregulated. In 1980, the overall pattern was similar to that in Banon Creek, but during the low flow period from late July through October, discharge was frequently zero. During such periods, the upper sections in particular consisted primarily of isolated pools separated by stretches of subterranean flow. In 1981, the general pattern of seasonal variations in Bush Creek was again similar to that in Banon Creek. By the second week in July, the discharge was zero.

In 1980, the general patterns of variation in water temperatures in the two study streams were similar. Temperatures in both streams peaked in mid-August. The peak temperatures were somewhat higher in Bush (mean weekly 18°C) than in Banon (16°C), presumably a result of the very limited discharge.

In 1981, temperatures in the two streams were similar early in the study period. In April, mean weekly temperatures declined by about 2°C in Banon Creek, but only by 0.5°C in Bush Creek. Thereafter, though the pattern of fluctuation was similar, temperatures remained about 1.5 to 2.0°C higher in Bush Creek than in Banon Creek.

Dissolved oxygen concentrations are largely a function of water temperature, high at low temperatures and low at high temperatures. In the two study streams, oxygen concentrations were generally high, with weekly means ranging from 8 to 13 mg/L in Banon Creek and from 8 to 12.5 mg/L in Bush Creek.

Conductivity was generally lower in Banon than in Bush Creek. In the former, weekly mean conductivity values ranged from 40 to 180 µmhos, highest during July of both years. Ordinarily, conductivity could be expected to remain high during the summer period of low discharge as groundwater comes to constitute a greater proportion of the total flow. The decline which occurred in Banon Creek in August was probably the result of dilution of higher conductivity groundwater by releases from the headwater lake.

In Bush Creek, conductivity values ranged from 55 to 360 µmhos, with high values recorded over the long period of low flow from mid-July to the end of October when groundwater was presumably a major contributor to streamflow.

4.1.2 Stream Habitats

Data describing the characteristics of stream habitats in Sections 1 to 10 in Banon and Bush creeks are presented in Tables 1 and 2. In both streams, the study reaches were selected to be relatively homogeneous and, as might be expected, values for many parameters are often similar among sections in the same stream. This is true, for example, of both streams with respect to width, depth, and velocity measurements, and substrate composition, bank erosion, and cover characteristics. The major differences among sections within the same stream occurred in substrate vegetation and gradient. In both streams, substrate vegetation varied widely among sections. Mean gradients within sections also varied widely. In Banon Creek, gradients tended to be higher in the sections upstream; in Bush Creek, sections of high gradient (2.3 to 3.1% in the vicinity of waterfalls) were interspersed with sections of low gradient (0.8 to 1.6%).

The major differences between the two streams were in width and velocity measurements, both of which were higher in Banon Creek, the larger of the two streams. In addition, substrate vegetation, though low in both streams, was proportionately lower in Banon Creek.

4.1.3 Habitat Evaluation

Stream habitat ratings and predicted standing crop for each section of Banon and Bush creeks are summarized in Tables 7 and 8 respectively. The data suggest that productivity within each study stream may vary considerably between sections, particularly in Banon Creek where both the highest (6.1 g/m^2) and lowest (0.4 g/m^2) predicted values for individual sections were recorded. The overall predicted standing crop for Bush Creek (2.7 g/m^2) is five to six times greater than that of Banon Creek (0.5 g/m^2), largely because of the differences in the relative abundance of substrate vegetation (i.e. moss and algae) in the two streams.

4.2 Fish Movements

4.2.1 Initial Movements After Stocking

4.2.1.1 Coho Fry

Data summarizing the initial movements of coho salmon fry during the first 20 to 30 days after stocking are presented in Tables 9 and 10. The data show that, in both streams, coho were much more likely to move upstream than downstream, a tendency that decreased in the later stockings in Bush Creek (where coho were scatter planted), but increased in Banon Creek (where coho were point planted). In both streams, the number of coho moving upstream averaged 11.2% of the number of coho originally stocked in each section (Banon Creek range 0.2 to 41.0; Bush Creek range 1.6 to 32.4). In Banon Creek, the proportion of the coho originally stocked which moved downstream averaged only 1.1%, about 1/10 of those which moved upstream. In Bush Creek, the proportion of downstream migrants was 2.7%, about 1/4 of those which moved upstream.

A tendency to upstream movement in hatchery-reared fry has been previously described by Glova (1978a) and was considered to be a conditioned response to the unnaturally high densities experienced in hatcheries. Glova seems to be suggesting that hatchery fry move upstream searching for other fry in an attempt to re-form the kind of dense grouping or school to which they have become accustomed in the hatchery. If so, this would explain the difference in the movements of fry planted in Bush and Banon creeks during the first stocking.

The Bush Creek fry, which were scatter planted, would be expected to show a greater tendency to move upstream in search of one another. Banon Creek fry, which were point planted, might be expected to be more stationary because they were already in close contact with one another.

Further support for this argument comes from the fact that, in Bush Creek, the proportion of fish moving upstream was inversely related to stocking density--that is, fish stocked at lower density would have the greatest difficulty in locating other fish and would therefore be expected to be more active in their search.

The foregoing explanation does not account for the movements of hatchery coho planted late in the study. In this instance, the point plants in Banon Creek showed a greater tendency to upstream movement that the scatter plants in Bush Creek, the reverse of the tendency in July. The reasons for this reversal are unknown. One possibility is that declines in temperature and photoperiod influence the behaviour of fry which, at this time of year, are normally dispersing to overwintering areas. Bustard and Narver (1975) have described the movements of coho fry to overwintering areas providing cover and protection from high-velocity flows. While this might account for differences in the movements of scatter and point planted fish, it does not explain why fish planted at the lowest densities show the greatest degree of movement.

The behavioural mechanisms controlling the dispersion of hatchery coho fry are obviously complex. Dispersion behaviour is, however, something that must be considered in developing planting strategies. It appears, for example, that if rapid dispersal of fish from point plants is desirable, that such plants should only be done in late summer or fall. Seasonal variation in the dispersion of hatchery-reared coho fry is one subject which deserves further study.

4.2.1.2 Cutthroat Trout

Data describing the movements of both young-of-the-year and older cutthroat trout during the first 20 to 30 days after stocking (Tables 9 and 10) do not provide any clear evidence that stocking coho fry has an significant effect on the movements of cutthroat trout. There were, however, a number of difficulties in interpreting the data:

1. The control sections in the two streams were not weired, and valid comparisons between control and experimental sections could not be made; however, for the one-month period after the first stocking, a kind of control is available because counts were made of the numbers of young-of-the-year and older cutthroat trout moving downstream from unstocked waters upstream of the three experimental sections, and upstream from unstocked waters downstream of the three experimental sections.
2. The numbers of cutthroat trout fry in each section were not known prior to the early coho stockings, because the fish were too small to be accurately censused.
3. Cutthroat trout fry captured during the early aftermath of the earliest stocking were only recently emerged and their movements downstream may have been part of a normal post-emergence dispersal rather than an effect of displacement by coho.

In Bush Creek, there was little apparent movement of cutthroat trout fry at any time during the study. Only 25 were captured in total, 20 (80%) moving upstream and 5 (20%) downstream. In the one-month period after the July planting, an average of 4.3 fish moved upstream and 1.0 fish moved downstream in the three experimental sections. At the same time, two fish moved upstream from unplanted waters and six moved downstream from unplanted waters. In the August and October plants, where the initial densities of cutthroat trout fry were known, but the number of fry captured within 20 to 30 days represented only a small fraction (0.0 to 1.4%) of the total present. These data suggest that the movements of young-of-the-year cutthroat trout in Bush Creek represent the normal, random movements of fry and that there was little, if any, displacement by coho fry.

In Banon Creek, considerably more young-of-the-year cutthroat trout were captured in traps than in Bush Creek. Overall, 118 were captured, 8.5% moving upstream and 91.5% moving downstream. Most of the captures were made during the one-month period after the first planting when 78 were captured, one moving upstream and 77 moving downstream. Most of the latter were taken in the downstream trap on Section 1, which had the highest coho stocking density. During the same one-month period, four young-of-the-year cutthroat trout moved upstream from unstocked areas downstream of the three experimental sections and seven fish moved downstream. This indicates only limited movements by cutthroat trout in unstocked segments of the stream and suggests, first, that only recently emerged cutthroat were displaced by coho fry, and second, that the effect was only seen at high stocking densities. The qualifications listed above should, however, be kept in mind.

With respect to older cutthroat trout, no large numbers were captured moving in either stream; but, in some instances, the movements did represent a substantial portion (to 15.3%) of the total population.

In both streams, there was a greater tendency for fish to move upstream than downstream; moreover, total movements were greater after the first stocking than after either the second or, especially, the third.

A comparison of the movements of older cutthroat trout during the one-month period immediately after the July planting of coho fry, with the movements of older trout in unstocked areas suggests that coho fry do, in fact, displace older cutthroat trout. In Banon Creek, an average 6.5% of the older trout present in the three experimental sections moved upstream while 3.3% moved downstream. This was at a time when there was no recorded movement of fish either upstream or downstream from unstocked areas. In Bush Creek, the comparable mean figures for the experimental sections were 4.0% upstream and 1.3% downstream when, again, there was no recorded movement from unstocked areas. Glova (1978a) also found that hatchery coho fry displaced the older cutthroat trout from pools.

In summary, though the data are not conclusive, it does appear that stocked hatchery coho fry did displace cutthroat trout. In Banon Creek, both young-of-the-year and older cutthroat trout appear to have been displaced, at least as a result of the earliest stocking. In Bush Creek, the data suggest that only older fish were displaced.

4.2.2. Longer Term Movements

4.2.2.1 1980 Movements

All coho fry trapped during the period the traps were in place (approximately 20 to 30 days after each section was stocked) were killed. For this reason, there are no data describing the extent to which these fish might have dispersed had they been given the opportunity. Some data are available, however, describing the distribution of coho fry after the traps had been removed and the fish had overwintered.

Table 11 presents data describing the distribution of coho fry, planted in July and August, during the period 15 to 30 October. Of 650 fish stocked 21 July, and subsequently captured in Banon Creek during late October, only five (0.8%) were found outside of the section in which they had originally been stocked, all of them one section upstream. Of the 452 coho fry stocked 30 August and recaptured in late October, 78 (17.3%) were found in other sections. Most of them (76 fish) had moved downstream, the largest group as far as five sections downstream (from Section 6 to Section 1). Only two of the August stocking had moved upstream, both of them only one section.

The foregoing suggests that, in Banon Creek, fish stocked in July have little tendency to move during periods of low flow, which agrees with the information presented earlier in Section 4.2.1.1. Fish stocked in August, on the other hand, show considerably more movement, especially downstream. The increased tendency among later stockings to disperse also agrees with the information presented in Section 4.2.1.1 above. The preferred direction of movement is, however, the reverse of that indicated by trap catches in the immediate post-stocking period—downstream rather than upstream.

The data for Bush Creek (Table 11) indicate that there was relatively little dispersal after the initial post-stocking movements. Of 497 fish recaptured in late October, only five (0.1%) had moved even one section, all of them from the July stocking and all of them upstream.

4.2.2.2 1981 Movements

Some additional information on longer term movements prior to the smolt run is provided by recaptures of coho yearlings stocked in 1980 and recaptured early in 1981. The data for Banon Creek include recaptures in the study reach 23 March to 14 April 1981, together with recaptures of fish in the reservoir downstream of the study reach 14 to 22 May 1981. The data for Bush Creek include only recaptures made in the study reach, 5 through 20 March 1981.

The surveys of Banon Creek reservoir downstream of the study reach were conducted primarily to determine whether fish marked (by clipping the lower lobe of the caudal fin) in the study reach between 23 March and 14 April had by-passed the downstream smolt trap. Baited Gee minnow traps were placed in the reservoir at four locations around its perimeter.

A total of 183 coho was captured, all of them in a logjam near the inlet stream. Of these, only two had been previously marked during the early spring survey upstream. Since the ratios of marked to unmarked fish (1:91.5) in the reservoir was very much higher than that recorded at the smolt trap (1:5.3), it was concluded, first, that the smolt trap was efficient in taking a large proportion of downstream migrants (all of which were killed at capture), and second, that most of the fish in the reservoir were fish which had moved downstream before the smolt trap was in place, presumably during the winter. The smolt trap catches are, therefore, thought to provide a good indication of the numbers of juvenile coho surviving the winter in the study reach.

A Petersen mark-recapture experiment was conducted on the juvenile coho concentrated at the reservoir inlet. During the period from 14 to 18 May, 86 fish were marked by clipping the upper lobe of the caudal fin. During a subsequent period, from 19 to 22 May, 88 fish were captured of which nine were marked recaptures, giving a population estimate of 774 juvenile coho with 95% confidence limits of 428 to 1549 fish. Of the total capture of 183 fish, 77.6% were stocked 21 July in Sections 1 to 3; 20.8% were stocked 30 August in Sections 4 to 6; and 1.6% were stocked 8 October in Sections 6 to 9.

Evidently a large number of juvenile coho had moved downstream out of the study reach, to take up residence in the vicinity of the logjam. The fate of these fish, had there been no logjam and no reservoir is a matter of speculation; although in the absence of these features, the overwinter survival of the coho would presumably have been much lower. The importance of the reservoir for overwintering is illustrated by the fact that its estimated fish population (774) is about 70% of the number of fish originating in the study reach and captured in the smolt trap (1101).

In Banon Creek, a considerable dispersal of juvenile coho occurred over the winter, including movements within the study reach (Sections 1 to 10) into a tributary stream located between Sections 7 and 8, and downstream into the reservoir (Figure 5). In all sections except Section 7, the net movement of fish was downstream. In Section 7, the net movement of fish was 120 m upstream to the small tributary stream described above. In addition, some fish from Sections 8 and 9 moved downstream to enter the tributary.

The overall net movement of coho juveniles in Banon Creek (regardless of direction) was 230 m, ranging from 43 m in Section 1 to 510 m in Section 9. The greatest individual movement upstream was 1200 m by a fish stocked in Section 1 and subsequently recaptured in Section 7; the greatest downstream was 1950 m by a fish stocked in Section 9 and subsequently captured at the logjam at the reservoir inlet.

In Bush Creek, coho stocked 19 July and 30 August showed relatively little movement in comparison with those stocked in Banon Creek (Figure 6). Fish stocked in Sections 1 to 10 showed a net downstream movement of only 45 m, ranging from a net upstream movement of 23 m for fish stocked in Section 1 to a net downstream movement of 154 m for fish stocked in Section 6. Fish stocked 8 October in Sections 7 to 9, in contrast, were more mobile and moved upstream a net 236 m. Most of these fish entered a tributary stream located just above Section 9.

The data for both Banon and Bush creeks indicate that juvenile coho will move upstream distances of 200 to 400 m to enter tributary streams to overwinter. Their ability to detect tributary streams may be related to proportionate discharge—that is, tributaries which constitute a relatively large proportion of the total mainstem flow may be detected at greater distances downstream.

4.2.3 Spring Downstream Movements

4.2.3.1 Coho Smolts

In Banon Creek, no significant downstream movement of coho smolts occurred between 9 and 31 March (Table 12). In early April, however, smolts from the July and August 1980 stockings began moving downstream, presumably in response to a peak in discharge which occurred during this period (Figure 3). In contrast, fish stocked in October 1980 did not move downstream during this period. As described earlier, however, most of the fish from this stocking overwintered in a small tributary and may not have been influenced as much by fluctuations in discharge in Banon Creek.

After the peak in early April, downstream movements declined, rising again to a second, larger, peak between 21 and 31 May, a period of declining discharge and increasing water temperatures (Figure 3). Downstream movements had ceased by late June. Other than the aforementioned absence of an early April peak among fish stocked in October, there were no apparent differences in the seasonality of downstream movement among either stocking dates or stocking density.

In Bush Creek, there was only a single peak in downstream movement during the period 11 to 20 May (Table 13), somewhat earlier than the second peak in Banon Creek. Again, this was a period of declining discharge and rising temperatures. By early June, downstream movements of coho smolts had largely ceased, 10 days or so before the cessation of movements in Banon Creek. The higher temperatures in Bush Creek, as well as the more rapid decline in discharge, may have been responsible for the earlier migration.

4.2.3.2 Cutthroat Trout

A total of 351 cutthroat trout moved downstream through the smolt trap on Banon Creek during the period 4 March through 30 June 1981 (Table 14). The major movements occurred during the period 1 May through 30 June with a broad peak 11 May through 10 June. The migrants included primarily 1, 2, and 3 year old fish with a few very large individuals, one 390 mm in fork length. At least part of the movement was probably a post-spawning migration of fish returning to the reservoir. Because only eight cutthroat trout were captured in the upstream trap, the upstream spawning migration presumably occurred before 4 March.

In Bush Creek, 125 trout moving downstream were captured during the trapping period (Table 14). Most of this movement occurred between 23 April and 20 May, with peak movements in late April. As was the case for coho smolts, the movement of trout in Bush Creek was several weeks earlier than in Banon Creek. In contrast to Banon Creek, most of the downstream migrants were yearling fish and relatively few were older fish (Figure 7).

4.3 Survival

4.3.1 Juvenile Coho

The coho survival data presented in this section are based on those coho which remained within the two study areas, from the time they were stocked as fry until the time they emigrated as smolts. In this study, fish which moved out of the experimental sections during the first 20 to 30 days after being stocked, or which moved downstream out of the study reaches during the winter period, were treated as mortalities.

4.3.1.1 Summer Survival

To 31 October 1980, survivorship curves for coho juveniles in Banon Creek (Figure 8) and Bush Creek (Figure 9) show a pattern typical of many juvenile fish populations—a rapid initial decline in numbers shortly after stocking, followed by a period of reduced mortality. For fish stocked between 19 to 21 July and 8 October, this pattern was more pronounced at high densities, and suggests that, for fish stocked at these times, the initial mortality in both streams was largely density dependent. Fish stocked 30 August in both streams also showed a rapid initial decline in numbers, but survival of these fish did not appear to be density dependent.

In Banon Creek, overall survival (Table 17) during the period after stocking to 31 October increased with later stockings—from 24.4% (range 16.9 to 33.3) for fish stocked to 19 July, to 31.2% (range 29.4 to 33.3) for fish stocked 30 August, to 74.6% (range 62.3 to 88.9) for fish stocked 8 October. In Bush Creek, overall survival (Table 18) was similar during the same time periods—slightly higher for fish stocked 21 July (28.6%, range 20.2 to 43.2), lower for fish stocked 30 August (24.8%, range 20.8 to 32.8), and higher again for fish stocked 8 October (89.3%, range 71.4 to 100.0).

4.3.1.2 Winter Survival

Over the winter, 31 October 1980 to 1 March 1981, there was no apparent relationship between coho survival and either stocking time or stocking density in Banon and Bush creeks (Tables 17 and 18). In Banon Creek, the overall survival of coho juveniles was 64.7%, ranging from an average high of 82.0% for fish stocked 30 August, to an average low of 49.6% for fish stocked 21 July. In Bush Creek, overall overwintering survival was even higher, 91.2%, ranging from 83.9% for fish stocked 8 October to 96.7% for fish stocked 30 August.

4.3.1.3 Spring Survival

During the spring period, 1 March to the smolt migration in May and June, the overall survival of coho juveniles in Banon Creek was relatively high (68.7%), approximately the same as survival over winter, and again apparently independent of density. In Bush Creek, spring survival was very low (38.6%), and apparently density dependent for fish stocked in July and August. For fish stocked in October, however, spring survival appeared to be inversely related to density.

The reasons for the unexpectedly low survival of the medium and low density Bush Creek October stockings are unknown. The pattern does not conform to that established by previous stockings in either stream, and suggests that some unusual circumstance was responsible. One possibility may be related to the presence of a small stream tributary to Bush Creek just upstream (within 10 m) of Section 9. This study (Section 4.2.2.2) and others have shown that juvenile coho frequently move up into small ephemeral tributaries to overwinter. Bustard and Narver (1975) suggest survival in such tributaries probably depends on weather conditions, and describe an instance in which dead coho fry were found in dried up pools following a September freshet. These fry presumably entered the tributary during the freshet and were then trapped as water levels fell. Something similar may have happened in Bush Creek.

It may be significant that the lowest survival (an estimated four smolts from 75 fish stocked) occurred among fish stocked in Section 9, the section closest to the tributary, and the next lowest survival among fish stocked in Section 8, immediately downstream.

Studies on Carnation Creek (Narver 1978) show a coho overwintering survival averaging 21% for the period September to May, both during winter (when discharges are high and water temperatures are low) and early spring (when discharges are declining and water temperatures are rising). During approximately the same period, survival in Banon and Bush Creeks was somewhat higher, 36% in the former and 27% in the latter.

A separation of winter (31 October to 1 March) data from those for the spring period (1 March to smolting) indicates that mortality during the winter, when physical conditions and nutrient availability are probably at their worst, is no greater than during the spring. In fact in Bush Creek, the reverse is true. Survival during the winter period is two or three times greater than that recorded during either summer or spring. In Banon Creek, survival during the winter was higher than that recorded in summer, and the same as that recorded during the spring.

4.3.1.4 Smolt Production

Figure 10 summarizes the major differences in the survival patterns of coho in the two study streams. In Bush Creek, overall coho survival to 1 March was 43.4%. In Banon Creek, it was much lower (28.1%), largely because of the lower winter survival in that stream. Lower winter survival was, however, compensated by higher spring survival. As a result, overall smolt production in both streams was almost the same—8.4 smolts/100 m^2 (10.4 smolts/100 fry stocked) in Banon Creek, and 8.5 smolts/100 m^2 (10.5 smolts/100 fry stocked) in Bush Creek.

The reasons for the difference in spring survival in Banon and Bush creeks are not definitely known. The spring period is, however, a period of rapid growth for both cutthroat trout and coho in the two streams (Section 4.4.). Because of the much higher densities of cutthroat trout in Bush Creek (Sections 4.3.2, 4.3.3), both interspecific and intraspecific competition may have been much more intense than in Banon Creek.

4.3.1.5 Summary of Coho Survival Data

A summary of the survival data for juvenile coho stocked in Banon Creek, based on the detailed data provided in Table 17, indicates both that survival was highest in later stockings and that it was highest at low density stockings. Survival data for Banon Creek coho may be summarized as follows:

Experimental Group	Mean Survival (%)	Mean Number of Smolts Produced (N/100 m2)
Stocking Date		
21 July	7.7	6.7
30 August	13.5	9.1
8 October	32.6	9.7
Stocking Density		
High	14.1	11.8
Medium	15.7	8.8
Low	24.1	4.8

Smolt production, as the number of smolts produced per unit area, showed a different pattern with the highest production from later stockings at high densities.

Similar data for Bush Creek indicate that survival was again highest in later stockings and, considering the July and August stockings only, at low densities. Because of the unusually low survival rates for the low and medium density October stockings, the relationship of survival to stocking density changes if all three stocking dates are considered. Survival data for Bush Creek coho may be summarized as follows:

Experimental Group	Mean Survival (%)	Mean Number of Smolts Produced (N/100 m2)
Stocking Date		
19 July	9.9	9.1
30 August	11.5	6.0
8 October	21.6	7.3
Stocking Density (July and August stockings only)		
High	7.7	9.7
Medium	7.1	7.3
Low	17.3	5.7

The greatest influence on the survival data for juvenile coho in Banon Creek may be summer survival, which appeared to be density dependent, probably as a result of intraspecific competition. In contrast, both winter and spring survival appear to be density independent. The causes of mortality from fall through to smolting are not definitely known, but may be related to severe physical conditions, inadequate nutrition, and predation (Bustard and Narver 1975) as well as competition.

Factors governing the survival of juvenile coho in Bush Creek during summer and winter appear to be similar to those in Banon Creek--density dependent during summer, and density independent during winter. The sudden mortality which occurred in the spring is unusual, however, in that it may have been density dependent, possibly because of greater interspecific competition with cutthroat trout.

4.3.2 Cutthroat Trout Young-of-the-Year

Data describing the seasonal variations in cutthroat trout fry abundance in each section are presented in Figure 11 and Table 19 for Banon Creek, and Figure 12 and Table 20 for Bush Creek. Table 21 summarizes density (numbers/m^2), survival (%), and mortality rates (Z). The data on survival cover only the latter part of the study period (from 8 October 1980 to 10 June 1981). Because fry were too small to be effectively sampled earlier in the study, the impact of early coho stocking on cutthroat fry could not be assessed. By the time fry could be accurately censused, most of the impact of early coho stockings on cutthroat fry may have already occurred.

In Banon Creek, the overall density of cutthroat fry on 8 October was 0.07 fish/m^2, ranging from 0.03 to 0.13 fish/m^2 among sections (Table 21). In Bush Creek cutthroat fry densities on 8 October were considerably higher--0.16 fish/m^2 overall, ranging from 0.07 to 0.32 fish/m^2 among individual sections. In both streams, the overall densities of cutthroat fry on this date were considerably lower than the mean density of coho fry (0.22 fish/m^2 for both streams) on 31 October (Tables 17 and 18). The following spring, after the coho smolts had emigrated, the overall densities of the same year class of cutthroat fry had declined in both streams to 0.04 fish/m^2 (a 43% decline from 8 October) in Banon Creek, and to 0.12 fish/m^2 (a 25% decline) in Bush Creek.

A comparison of the survival of cutthroat fry in stocked sections with that in control sections suggests that coho stocking may indeed have adversely affected the survival of cutthroat fry (Table 21). In both streams, apparent survival was higher in the control sections than in the stocked sections—in Banon Creek, at least 42.9% higher, and in Bush Creek, at least 25.0% higher. An apparent survival in excess of 100% in the control sections of both streams indicates that fish moved into these areas from outside.

In Banon Creek, there was no clear relationship between the survival of cutthroat fry and either time of coho stocking or coho stocking density. In comparison to the control section, overall survival was lowest in the section stocked 30 August (41.8%), intermediate in the sections stocked 21 July (57.1%), and highest in the sections stocked 8 October (84.6%). Survival was lowest in the high density sections (51.1%), intermediate in the low density sections (67.1%), and highest in the medium density sections (72.0%).

In Bush Creek, there was again no clear relationship between cutthroat trout fry survival and stocking density (Table 21). It does appear, however, that the apparent survival of cutthroat fry was highest for early stockings where overall survival was 93.0% (32% less than the apparent survival of fry in the control section), and lowest for late stocking where survival was 53.0% (72% less than apparent survival in the control section). It should be noted, however, that the estimates of cutthroat fry in those sections stocked with coho in July and August must be considered maximal because the major impact by coho on cutthroat fry may have already occurred prior to the first accurate censuses in mid-September. In this instance, it may be significant that the estimated cutthroat fry densities in sections stocked in July and August were three times lower in early October than densities in the sections stocked 8 October.

4.3.3 Older Cutthroat Trout

Data describing seasonal variation in the abundance of the older cutthroat trout in each section are presented in Figure 13 and Table 22 for Banon Creek, and in Figure 14 and Table 23 for Bush Creek. In both streams, seasonal patterns of abundance of cutthroat trout were influenced by seasonal movements of fish as well as by mortality. To obviate much of this short-term variation, the data describing density and survival in Table 24 are presented for only two periods—at the time each section was stocked in 1980, and on 10 June 1981 after most of the coho had left the stream.

In Banon Creek, the mean initial density of older cutthroat at the time of stocking was 0.075 fish/m^2. The density in the control section also averaged 0.075 fish/m^2—ranging from 0.092 fish/m^2 on 21 July, when the first stocking was made, to 0.004 fish/m^2 on 8 October, when the last stocking was made. In Bush Creek, where densities of older cutthroat trout were considerably higher, the average density for all stockings was 0.170 fish/m^2, over twice the average density in Banon Creek. Average density in the Bush Creek control section was 0.089 (lower than initial densities in eight of the nine experimental sections), ranging from 0.127 on 19 July to 0.051 on 8 October.

On 10 June 1981, the year after coho stocking, the mean density of older cutthroat trout (exclusive of the 1980 year class) in stocked sections of Banon Creek was 0.032 fish/m^2, a decline of 57% from the mean initial value. In Bush Creek, the mean density was 0.074 fish/m^2, a decline of 56.5% from the mean initial value.

Comparisons of older cutthroat trout in control groups with those in stocked sections (Table 24) suggest that the survival of these fish was affected by coho stockings. In Banon Creek, the results were variable. In comparison to cutthroat survival in the control section, that in the stocked sections was 6.6% higher in July, 3.6% lower in August, and 12.2% lower in October. For stockings at low densities, irrespective of stocking period, survival was 9.3% higher; for stockings at medium densities it was 8.2% lower; and for stockings at high densities it was 10.3% lower. In Banon Creek, it appears that the overall impact of coho on older cutthroat trout was greatest at higher densities and later stockings.

In Bush Creek, cutthroat trout densities in the control section were higher on 10 June 1981 than they were in October 1980, indicating that some older cutthroat trout had moved into the area between the two census dates. In comparing survival of control and experimental groups, a maximum survival of 100% rather than the 152.9% indicated by the data has been assumed. This change, though it increases the apparent survival of cutthroat trout in the experimental groups, does not affect the general pattern, which is similar to that of Banon Creek. In comparison with survival in the control section, that of the July stocking was higher (+7.1%); that of the August and October stockings lower (-14.4% and -45.8%, respectively). In addition, for stockings at low densities, irrespective of stocking period, survival was higher (-1.1%) than it was for stockings at either medium (-16.8%) or high (-35.2%) densities.

4.4. Growth

4.4.1 Coho Fry

4.4.1.1 Length and Weight

Data describing the growth in length and weight of juvenile coho salmon in Banon and Bush creeks are presented in Tables 25 to 28. Comparisons of growth based on these data are complicated by the considerable time, two to three weeks, required to complete each census (Tables 5 and 6).

Figure 15 illustrates seasonal growth in weight for juvenile coho stocked at three different times (July, August, and October) in the two streams. The data for each stocking date have been averaged for the high, medium, and low density stockings to emphasize the differences in growth patterns among fish stocked at different times. The figure illustrates the following:

1. For approximately one month after stocking, the August stocked fish, which were in poor condition, gained weight at a relatively greater rate than either the July or the October stocked fish. The latter, which were in high condition at stocking, actually lost weight in both streams.
2. During the winter, growth in weight was probably low for each stocking group in both streams. In Banon Creek, the more rapid winter growth rates of fish stocked in July and August were probably an artifact of sampling, in that the sampling period for these groups was quite late, in comparison to the comparable group in Bush Creek, and was likely to have included a period of rapid spring growth in late March and early April.

3. During the spring period, there was rapid growth in most groups prior to the smolt migration. In Banon Creek, the July and August stockings had greater spring growth rates than those stocked in October. In Bush Creek, all three groups grew rapidly.

4. Despite differences in their seasonal growth patterns, the July and August stockings in both creeks migrated seaward at similar weights. Most of the difference in weight between smolts in the two earliest stockings was probably the result of an additional few weeks of growth for Banon Creek smolts, which migrated later (Section 4.2.3.1). In both streams, smolts of the October stocking were by far the largest, more so in Bush than in Banon Creek.

Generally, coho stocked at high densities grew more slowly and were smaller, in terms of both length and weight, than fish stocked at lower densities (Tables 25 to 28). The only exception was the group of fish stocked in Banon Creek in July. Among these, the general pattern held through October 1980, but in samples of juveniles taken during March 1981 and of smolts taken in May and June, both the lengths and weights of fry planted at high densities were significantly greater ($p<0.05$) than those planted at low densities.

4.4.1.2 Instantaneous Growth Rates

Instantaneous growth rates, based on weight data in Tables 25 and 27, were calculated for the period from stocking to smolt migration. In order to determine whether there was any pattern in the differences among stocking times and densities, instantaneous growth rates were summarized as follows:

Experimental Group	Mean Values (Gw)	
	Banon Creek	Bush Creek
Stocking Date		
21 July	2.042	1.877
30 August	1.951	1.821
8 October	0.461	1.206
Stocking Density		
High	1.446	1.517
Medium	1.495	1.686
Low	1.513	1.702

The summary indicates that, in both streams, growth rates tended to be higher for earlier stockings and for lower stocking densities. The differences are greatest among stocking times.

4.4.1.3 Condition

Figure 16, based on the data presented in Tables 29 and 30, illustrates seasonal changes in condition for fish stocked in the two study streams at different times of the year, irrespective of density. The data indicate that:

1. The condition of fish at stocking reflects the hatchery regime under which they were reared, as described in Section 3.2;
2. In three of the four groups stocked in July and August, condition improved rapidly during the month or so after stocking. The exception was the July stocking in Bush Creek, for which condition remained relatively stable;

3. In the fall of the year, almost all groups showed a decline in condition, the exception again being the July stocking in Bush Creek, where condition was already low. The fall decline was shared by the newly stocked October groups in both streams. In this instance, at least part of the loss in condition may have been attributable to the stress of adapting to circumstances different from the hatchery;
4. In every instance, condition increased over winter;
5. In every instance, condition declined dramatically from late February and early March to smolting; and
6. At smolting, condition factors were more uniform among the various groups, with means ranging from 1.029 to 1.113, than at any other time.

4.4.2 Cutthroat Trout Young-of-the-Year

4.4.2.1 Length and Weight

Data describing the growth in length and weight of cutthroat trout young-of-the-year in Banon and Bush creeks are presented in Tables 31 through 34. In assessing the data, the major concern was to determine whether the introduction of coho fry had had an adverse effect on the growth of cutthroat fry as evidenced by differences, within stocking dates, in the weights of cutthroat in sections stocked with coho at high, medium, and low densities.

Because of large differences, up to several weeks, in the census times for stream sections stocked during July, August, and October, most comparisons among stocking dates are suspect. Consequently, the comparisons discussed here are confined to the July 1981 sampling in Banon Creek, which took place over a four-day period, and the June 1981 sampling in Bush Creek, which took place over a seven-day period. Both censuses were made at the end of the smolt run in the respective streams, and should be representative of the maximum likely effects on growth.

The general growth patterns shown by cutthroat trout fry in the two streams are illustrated in Figure 17. The data presented are for cutthroat fry in Sections 1, 2, and 3 in each stream, but are typical for the populations as a whole. When the first samples were taken in August 1980, Bush Creek fry were already considerably larger than those in Banon Creek, probably because they emerged earlier. In both streams, growth was rapid into September, declining in October, and slowing even further through the winter. In the spring, growth rates again increased in both streams. At the end of the study, cutthroat yearlings in Bush Creek were still considerably larger than fish of the same age in Banon Creek.

For the sections stocked in July in Banon Creek, there was a tendency for the mean weight of cutthroat fry in Section 1 (high density stocking) to be less than that of fry in both Section 3 (low density stocking) and the control section. Some of these differences were significant (<0.05)—namely those between Section 1 and Section 3 in early in mid-September 1980 and July 1981; and those between Section 1 and the control in in September and October 1980 and early July 1981. Mean weights of fry in Section 2 (medium stocking density) were variable, sometimes the lowest (e.g. in October 1980) and sometimes the highest (e.g. July 1981) of the three groups.

In the August stocking in Banon Creek, there was also a tendency for mean weights of cutthroat fry in Section 4 (high density) to be less than those of fry in Section 6 (low density). The March sampling was the only exception. The differences in mean weights of fish in the two sections were significant for samples taken in late September and mid-October 1980. The mean weights of samples taken in Section 4 were similar to those in the control section, except in mid-October, when they were significantly smaller. Mean weights of cutthroat fry in Section 5 (medium density) were variable—lowest of all in September, highest in July, and intermediate at other times.

For the October stocking in Banon Creek, there was again a tendency for the fish in Section 7 (high density) to be smaller than fish in Section 9 (low density); however, since they were also significantly smaller on 2 October, before the coho were stocked in these sections, it is unwise to assess the effect of interactions with coho fry on this basis alone. A comparison of fry in Section 7 with cutthroat fry in the control section suggests, though, that fry in the high density sections were adversely affected in terms of weight gain. The two groups had identical mean weights before coho fry stocking, but there was a considerable (though not significant) difference in the weights of the two groups (1.0 gm) by the end of the study period in July 1981.

For the July stocking in Bush Creek, there was no clear relationship between stocking density and fry weight, either in comparisons among the groups planted at different densities, or of these groups with the control. (Tests of data for the control group with data for groups planted in Sections 7, 8, and 9 were not attempted for the March sampling period because the difference in sampling times, nine days, was considered too great to allow meaningful comparisons). The significant differences were those which occurred 20 to 22 October

1980 between the three experimental groups and the control group. The mean weight of the latter groups was significantly less than that of any of the experimental groups.

For the August stocking in Bush Creek, fry in Section 4 (high density) had lower mean weights than fry in either Section 5 (medium density) or Section 6 (low density) during each of four sampling periods. These differences were significant for the 20 to 22 September, 20 to 22 October, and 9 to 13 March sampling periods, but not in late June. The mean weights of the experimental groups were greater than those of the control group in September and October 1980, but less in March and June 1981. These differences were significant during the September and October sampling periods, but not later. In June, the mean weight of fry in Section 4 was significantly smaller than that of fry in the control group, but there were no significant differences between the mean weight of the control group and that of fish in either Section 5 or Section 6.

For the October stocking period, the pattern was similar to that described for the October stocking in Banon Creek. Throughout the study period, fry in the high density group again tended to be smaller than those in the medium and low density groups; but, as was the case with the Banon Creek fish, they were already significantly smaller than either of the two experimental groups on 2 October before the coho were stocked. Because of differences in sampling dates, the only valid comparisons between the experimental groups and the control group were for March and June 1981. In March, the mean weight of fry in Section 7 (high density) was significantly less than that of Section 8 (medium density), Section 9 (low density), or the control group. In June, there were no significant differences in mean weight between any of the groups.

The foregoing suggests that there is a tendency among almost all stocking groups in both streams for cutthroat fry in sections stocked with high densities of coho to grow more slowly than those in sections stocked with medium and low densities. A summation of data to mid-October (after the end of the summer growing season) and for June and July (after the coho smolt migration) illustrates this tendency (Table 35). The data, which were calculated as weighted means, suggest that:

1. Coho stocked at high densities adversely affect the growth of cutthroat fry; and
2. The effect is greatest when coho are stocked early in the year.

4.4.2.2 Condition

An examination of data describing condition factors (K) for cutthroat trout fry from the two study streams (Tables 36 and 37) revealed no consistent pattern in the variation of condition under different stocking time or stocking density regimes. One notable feature of the data was, however, the difference in the seasonal pattern of variation in condition factors between Banon Creek and Bush Creek (Figure 16). In Banon Creek, condition changed only minimally over winter, but increased rapidly in the spring. In Bush Creek, the pattern resembled that previously described for coho fry, increasing markedly over the winter and falling rapidly in the spring.

4.4.3 Older Cutthroat Trout

Data describing the growth in weight of cutthroat trout from the 1976 to 1979 year classes in each section of Banon and Bush creeks are presented in Tables 38 and 39, respectively. Because of the length of time between sampling periods for sections stocked at different times, these data were not used to make detailed comparisons. In addition, the sample sizes in most instances were relatively small and the variation within samples proportionately high. Consequently, only general patterns are described in the following sections.

4.4.3.1 Seasonal Growth

Figure 18, based on the data in Tables 38 and 39, illustrates the general patterns of growth of one, two, and three-year- old cutthroat trout in Banon and Bush creeks. Each point represents an average mean, based on the mean weight of fish in sections (including the controls) sampled at approximately the same time. In both streams, the growth patterns of all three age classes showed the following characteristics:

1. A period of very slow growth during summer and early fall low flow conditions. With the exception of three-year- old fish in Bush Creek, all fish lost weight at some time during this period. In Banon Creek, the loss was greatest among older fish, declining in younger fish;

2. A period of moderate growth during the winter from November to March. Presumably most of this growth occurred near the end of winter as water levels declined and temperatures increased. Growth was greatest in Bush Creek where fish increased their

weight by 18 to 31% over the lowest values recorded during the previous summer. Fish in Banon Creek showed an increase of only 11 to 15%, essentially the same weight they lost the previous summer;

3. A period of rapid growth during the spring from March to the end of the study in July. During this period, the growth rates of fish in Banon Creek were higher than those of fish in Bush Creek, and compensated for the lower growth rates in Banon Creek over winter. As a result, fish of each age class were the same weight in both streams at the end of the study, and the same as fish in the next oldest age class at the beginning of the study.

4.4.3.2 Effects of Stocking

The overall mean weights of one and two-year- old trout in sections stocked at the same time and density are summarized in Table 40 to 41. The data are presented for two times in each stream, October 1980 (following a period of relatively slow growth) and June and July 1981 (following a period of relatively fast growth).

Among one-year- old fish (Table 40), there was no clear relationship between stocking time and weight in either of the two streams. In most instances, fish tended to be largest in the sections stocked in October and smallest in the sections stocked in August. The exceptions were the fish in Bush Creek in June and July where the largest fish were those in the August stocking and the smallest were those in the July stocking. In comparison to fish in sections stocked at different times, the control fish were larger in Bush Creek during October, intermediate in Banon Creek during October, and smaller in both streams in June and July.

In both streams during October, one-year-old cutthroat trout in the sections stocked at high densities were consistently smaller than fish in both low density and control sections. This size difference suggests that coho have an adverse effect on the growth of yearling cutthroat trout during periods of low flow, and that the effect is greatest at high densities. The pattern, however, was reversed in June and July. In Banon Creek, the now two-year-old trout (fish from the 1979 year class) were largest in the high density sections, smaller in the low density sections, and smallest in the control section. There was no pattern among stocking densities in Bush Creek at this time, but, as was the case in Banon Creek, fish in the experimental sections were larger than fish in the control section.

Reasons for the apparently better growth by yearling cutthroat trout in high density sections in the spring are unknown and probably very complicated. It may be that the differences are simply an artifact related to the poorer survival of smaller fish at higher stocking densities. Alternatively, poorer overall survival at higher densities, regardless of fish size, may have resulted in better growth by the remaining fish because of a greater reduction in intraspecific competition.

In Banon Creek, the effects of stocking time on the growth of two-year-old fish from the 1978 year class (Table 41) appear very pronounced, with by far the poorest growth occurring in the sections stocked in July. There was, however, no clear pattern in Bush Creek in October, and only a slight indication of better growth by fish in later stockings at the end of the study.

Two-year-old trout in both streams in October showed better growth in the high and medium density sections than in the low density sections, possibly for the reasons described above for one-year-old fish. There was, however, no apparent pattern between the weight of fish and stocking density at the end of the study in early July. At this time, the weight of fish at all densities was lower than the weight of fish in the control section. In Bush Creek, in contrast, the average weight of fish at the end of the study was highest in the low density sections and higher in all sections than the control.

4.5 Production

Data summarizing production for coho and cutthroat trout in the two study streams are presented in Tables 42 and 43. More detailed data are presented in the Appendix to this report. In every case, the stream areas used in calculating production are those measured during the habitat survey at low flows, 22 to 25 September 1980.

4.5.1 Comparisons Between Streams

The available data indicate that Bush Creek was considerably more productive than Banon Creek. Total average production, including both cutthroat trout and coho salmon, was 2.95 g/m^2 for Bush Creek and 1.20 g/m^2 for Banon Creek for the period 8 October 1980 to 10 June 1981. (This period was the only one for which data were available for all life history stages, including young-of-the-year cutthroat trout, older trout, and coho fry.) The major differences in the total average production of the two streams was largely the result of differences in production by cutthroat trout—2.06 g/m^2 or about 70% of the total in Bush Creek, compared with 0.62 g/m^2 or about

52% of the total in Banon Creek. Values for the total average production of coho fry in the two streams were more alike—0.90 g/m^2 in Bush Creek and 0.58 g/m^2 in Banon Creek. Though the data discussed above are for the 8 October 1980 to 10 June 1981 period only, the same general differences are apparent for other, shorter, time periods.

Overall, the production data indicate that Bush Creek is two to three times more productive than Banon Creek. This conclusion supports the results of the habitat studies (Section 4.1.3) which predicted that Bush Creek was more productive than Banon Creek. The measured difference in production is, however, less than the five or six times predicted for two possible reasons: first, because of the stabilizing influence of the upstream reservoir on Banon Creek, which ensures at least minimal summer flows; and second, because of the downstream reservoir, which provides a haven for larger trout which could not normally be supported by the stream itself.

4.5.2 Coho Production

Coho production was somewhat higher in Bush Creek than in Banon Creek. The average total production, including all stockings and all densities from the time the fish fry stocked until they migrated as smolts (assumed to be 10 June 1981 for purposes of calculation) was 1.20 g/m^2 for Bush Creek and 0.91 g/m^2 for Banon Creek. The average total production for the period 8 October to smolting, when all groups were present in the streams, was 0.90 g/m^2 for Bush Creek and 0.58 g/m^2 for Banon Creek. A major factor in this discrepancy was the relatively high production of the groups stocked 8 October 1980, which averaged 1.53 g/m^2 (discounting the group stocked in Section 9 which seemed to have suffered some catastrophe), 220% greater than the average of the groups stocked in Sections 1 to 6 earlier in the year. In Banon Creek, the average production of the three groups stocked on 8 October was 0.20 g/m^2, only 26% of the average of the six groups stocked earlier.

An analysis of the seasonal patterns of production for coho salmon (Figure 19) indicates that production was relatively high in both streams in July, but declined through August and September to low or even negative values in October. Net production during the period 31 October through 1 March was relatively high, and high rates persisted through the smolt migration. The July and August stockings in the two streams follow this general pattern quite closely, but the October stockings are unusual in their negative production values during October, immediately after stocking. This reduction was probably an effect of the stress involved in adjusting to a new habitat after a long period of hatchery rearing. The October stocking in Bush Creek is further unusual in its very high production during the October to March and March to June periods.

Over most of the study period, accumulated production was greater in Banon Creek than in Bush Creek (Figure 19), though, by June 1981, the former was overtaken by the latter. The early advantage in production in Banon Creek was a result of the high production of the July stocking. During each of the subsequent sampling periods, however, total production in Bush Creek was greater, particularly during the period from 1 March to 10 June.

Table 44 summarizes a variety of data describing the production of coho fry in the two study streams. The data indicate that, in general:

1. The relationship of production to stocking data is quite variable. In Banon Creek, total production was marginally higher for the first stocking and lowest for the third stocking. For the period after 8 October, however, after all groups had been stocked, production was highest for the second stocking. In Bush Creek, both total production and production after 8 October were highest for the third stocking and lowest for the second.

2. The relationship of production to stocking density was the same for both streams. Total production and production after 8 October were highest in the high density sections and lowest in the low density sections.

3. In both streams. the $P/\bar{B}$ (production/mean biomass) ratio for the entire study period was greatest for the earliest stockings and for the lowest densities. For the period 8 October to smolting, however, it tended to be greatest for the second stocking, followed by the first and then the third. During this period $P/\bar{B}$ ratios again tended to be highest for low and lowest for high density stockings. It is noteworthy that the third stocking in Bush Creek, though it had the highest production, had the lowest $P/\bar{B}$ ratio among the three stockings.

4. Percent yield is defined here as grams of smolts produced per unit area divided by the grams of fry stocked per unit area, expressed as a percentage. Both figures are based on areas available within sections at summer low flow. Overall, there was a net loss in biomass, for each stocking time and for each density. With regard to stocking time, the best performances were for the second stocking in Banon Creek and the third stocking in Bush Creek. With regard to stocking density, the best performances were for the low density stockings in each stream.

4.5.3 Cutthroat Trout Production

As previously indicated (Section 5.1), Bush Creek is considerably more productive of cutthroat trout than Banon Creek. The difference in total production over the study period is primarily the result of much higher levels of production during the periods from 30 October to 1 March and from 1 March to 10 June (Figure 20). In addition, there is a longer period of negative production in Banon Creek than in Bush Creek.

In Banon Creek, overall mean production was either very small or negative from the beginning of the study in July 1980 to 1 March 1981. As a result, there was a net loss in accumulated production until the following spring. In Bush Creek, while there was a period of overall negative production in the fall (8 October to 30 October), net production was positive over the summer period and increased rapidly from 30 October 1980 to 10 June 1981. As suggested for coho, much of the production from 30 October to 1 March probably occurred toward the end of this period.

Figure 19 shows a comparison of seasonal patterns of production for cutthroat trout inhabiting the experimental sections stocked at different times during the study period with the production of cutthroat trout in control sections. Generally, the patterns of production for the various stocking dates within streams were more alike than those between streams. During the period after 30 October, production in the experimental sections in both streams was highest in the sections stocked in October and lowest in the sections stocked in July. In both streams, production in the control sections was intermediate and similar to that of experimental sections stocked in August. Earlier in the study period, before 30 October, production was low, particularly in Banon Creek, and variable among groups stocked at different times.

Data describing mean biomass ($\bar{B}$), mean observed production (P), and the ratio of these parameters ($P/\bar{B}$) are summarized for cutthroat trout in the two study streams in Table 45, according to the time and density that sections were stocked with coho fry. Comparable $P/\bar{B}$ ratios are presented for the control sections in the two streams and used to calculate values for expected production (EP) as the product of mean biomass for the experimental group and the $P/\bar{B}$ ratio for the control group:

$$EP = P/\bar{B} \text{ (control) } \times \bar{B} \text{ (experimental)}$$

Without exception, the expected production (based on the performance of cutthroat trout in the control group) exceeded the observed production of trout in the experimental sections, suggesting that the impact of coho stocking on production of cutthroat trout was negative. This impact appears to have been greater in Bush Creek, where differences in expected and observed production ranged from 25.9 to 41.8%, than in Banon Creek, where differences ranged from 2.0 to 15.0%. Nevertheless, observed production in experimental sections of Bush Creek still averaged three to four times higher than in Banon Creek.

With regard to differences in production among stocking dates, the impact in Banon Creek was greatest for the July stocking; in Bush

Creek, the impact was greatest for the second and third stockings. With regard to density, the impact in Banon Creek was greatest at medium stocking densities and lowest at low stocking densities. In Bush Creek, the impact was greatest at high and medium stocking densities.

5.0 GENERAL DISCUSSION AND CONCLUSIONS

The following discussion focuses on those aspects of the study most relevant in determining the best strategies for superimposing hatchery-reared coho fry on isolated cutthroat trout populations. In this discussion, survival is defined as the percent of stocked coho fry surviving to the smolt stage; production is defined as the number of smolts leaving the stream at the smolt stage; and net production is defined as the growth in weight by all fish over a specified period of time, including growth by fish that died over the period.

5.1 Coho Salmon

5.1.1 Survival

In both study streams, survival of coho fry to the smolt stage tended to be highest when coho fry were stocked at low rather than high densities, and late rather than early in the year (Section 4.3.1). The differences in survival were not usually large enough, however, to entirely compensate for the differences in the number of fry stocked at different times or densities. As a result, smolt production per unit area tended to be the opposite of survival.

High density stockings always produced more smolts per unit area than low density stockings, and low density early stockings produced more smolts than low density late stockings (Tables 17 and 18). High density early stockings, in contrast, produced fewer smolts than high density late stockings, but the difference was small in comparison to the difference in survival.

With regard to the relationships between survival, stocking density, and smolt production, the results of this study are similar to those described by Fraser (1969) who stocked coho and steelhead fry together over a summer in a controlled stream environment. Both studies indicate that, despite lower survival, high density stockings in the absence of older fish of the same species are likely to produce more fish than low density stockings. This consideration would be important in coho stocking programs when the value of the fry stocked is small in comparison to the value of the smolts produced. Mills (1969) showed, however, that high density spring stockings in streams with older fish of the same species (Atlantic salmon) resulted in much lower survival and approximately the same autumn densities as low density stockings.

Coho that remain for a second year in fresh water are not likely to be a problem in streams stocked with accelerated hatchery fry. None was found in either Banon or Bush creeks, despite intensive sampling after the smolt migration was complete. Residual coho are more likely to occur where either unfed, hatchery-reared fry or transplanted wild fry are stocked.

Typically, such fish would have slower initial growth than hatchery-fed fry, predisposing them to a longer period in fresh water before smolting. In some streams (e.g. Carnation Creek), the proportion of two-year-old coho in the smolt run is high (50%, Narver and Anderson 1974). In others, it is low—2.5% in the Cowichan River (Armstrong and Argue 1977) and 2.7% in the Big Qualicum River (Lister and Walker 1966). Annual variation can also be high (Argue and Armstrong 1977).

There were marked differences in the overall seasonal patterns of coho survival in the two study streams (Figure 10). Though survival during summer was similar, winter survival was much higher and spring survival was much lower in Bush Creek than in Banon Creek. The differences balanced each other and, as a result, overall survival was similar for the two streams. Overall smolt production (8.4 to 8.5 smolts/100 m^2) was also similar, though low in comparison with other streams (16 to 50 smolts/100^2; Lister and Walker 1966, Chapman 1965).

The difference in the seasonal patterns of survival in the two streams is one feature of the data with implications for the management of coho stocks. It has been suggested, for example, that one of the major constraints on coho production in many coastal streams is the lack of suitable overwintering habitat (Bustard and Narver 1975). Narver (1978) further suggests that improvement of overwintering habitat in such streams could markedly improve smolt production.

The data of the present study show, however, that in streams like Bush Creek, high (density independent) survival during the winter when growth is slow may be nullified by low (density dependent) survival during the spring when growth is rapid. The data suggest that the relationship between overwinter survival and smolt production is complex and deserves further study before any largescale programs devoted to improving overwintering habitat are undertaken. As Mason (1976) points out, any steps taken to relieve the limits on production in one season (in this case, winter) must be coordinated with similar steps to relieve the limits on production in other seasons (spring and fall).

5.1.2 Growth

Growth rates (Gw) were greatest for fish stocked at the lowest densities in each stocking period and for fish planted early in the study period (Section 4.4.1). The high growth rates of the fry planted in July and August did not, however, entirely compensate for the larger initial size of the fish planted in October. The data also suggest that, in both streams, growth during the first (summer) growing season was density dependent. During the second (spring) growing season, when most of the growth occurred, growth again appeared to be density dependent in Bush Creek, but less so in Banon Creek.

In both study streams, the average length of the coho smolts produced by the small fry stocked in July and August were within the upper range of fork lengths reported for one-year-old smolts in most other small streams (Chapman 1965, Narver and Anderson 1974, Argue and Armstrong 1977). The smolts produced by the large fry stocked in October, in contrast, were within the range usually reported for two-year-old smolts. The differences in size are an important consideration in formulating stocking strategies. Although the larger smolts are likely to have better survival at sea, Bilton (1978) indicates that this may result only in a greater return of jacks, with no difference in the number of other adults.

5.1.3 Production

Net production (g/m^2) tended to be greatest for coho stocked early in the year at high densities (Section 4.5.2). Efficiency of production, as indicated by P/$\bar{B}$ ratios, was also highest for early stockings but at low rather than high densities.

5.2 Cutthroat Trout

5.2.1 Survival

The concerns raised by Glova (1978a, 1978b) and Glova and Mason (1977a, 1977b) about the adverse impacts of juvenile coho salmon on isolated cutthroat trout populations appear correct. It seems that cutthroat survival was adversely affected by the presence of coho fry (Sections 4.3.2, 4.3.3). With regard to stocking density, the greatest effects on the survival of both young-of-the-year and older fish were associated with high coho stocking densities. With regard to stocking period, the survival of both young-of-the-year and older cutthroat trout appeared to be most adversely affected by the last stockings in October. The observed values for survival of young-of-the-year cutthroat trout are, however, for the period from October 1980 through June 1981 only, and do not include any mortality which might have occurred earlier among the July and August 1980 stockings.

Comparing results for the two streams, it seems that the impact of coho stocking on cutthroat survival was greater in Bush Creek, where the trout population was more dense, than in Banon Creek, where trout densities were low. The reasons for this difference are not definitely known, but probably involve a complex of factors. One possibility is that, because Bush Creek is subject to very low summer flows, coho and cutthroat are less able to segregate themselves among habitats and are forced into more intimate contact with one another. In Banon Creek, discharges are regulated above a minimal level by an upstream reservoir. In addition, the coho data (Section 4.3.1.4) suggest that, in Bush Creek, salmonids may have a longer period (spring and summer) during which factors affecting density dependent mortality are operative. In Banon Creek, density dependent mortality may operate over a shorter period (summer only).

5.2.2 Growth

The effects of coho stocking on the growth of young-of-the-year cutthroat trout were consistent for both study streams. High densities and early stockings both slowed the growth of cutthroat fry (Section 4.4.2), presumably as a result of interspecific competition. For older fish (Section 4.4.3), the results were variable and difficult to interpret, in large part because sample sizes were so small.

5.2.3 Production

The interpretation of production data for cutthroat trout in the two study streams is complicated by the lack of control over the number of trout in the experimental and control sections (Section 4.5.3). It is clear, however, that there was an adverse effect of coho stocking on production of cutthroat trout which was greater in Bush Creek than it was in Banon Creek. This effect was largely the result of the differences in trout survival in the two streams (Section 5.2.1). In both streams, among stocking densities, the reduction in production was greatest in sections stocked with coho at high densities. Among stocking times, the adverse effects in Bush Creek were greatest for the August and October stockings; in Banon Creek, they were greatest for the July stocking.

5.3 Stocking Strategies

No single stocking strategy can be considered "best" under all circumstances. Biological as well as economic factors must be considered in making decision concerning stocking practices. The following sections discuss the kinds of information which should be considered with respect to the stocking of coho in isolated cutthroat trout streams, and comment on the advantages and disadvantages of representative strategies.

5.3.1 Stream Selection

Though the data are equivocal in the matter of stream selection (Section 4.3.1.4), it is to be expected that, in general, the most productive streams would produce the highest survival of stocked coho to the smolt stage. From the point-of-view of coho smolt production alone, the best streams for stocking are those which combine high productivity with adequate overwintering capacity. For this reason, candidate streams should be surveyed on at least two occasions before a final selection is made.

First, to provide a relative measure of probable production, streams should be examined during summer low flow, and the quality of salmonid habitat quantified using the methods of Binns and Eiserman (1979) or a similar technique. During this survey, trout biomass should also be indexed as a further indication of stream productivity. Second, streams should be examined during periods of high flow in the winter to assess the availability of suitable overwintering areas, particularly small tributary streams, side channels, side pools, and backwaters, and to determine which of these may be dry during the summer.

5.3.2 Method of Release

With regard to the distribution of release sites within streams, the most even distribution of stocked coho would be achieved by scatter planting. The data for Banon Creek suggest that point plants of fed hatchery fry would also produce a relatively even distribution of juvenile coho, particularly if the distance between planting sites did not exceed 230 m. This distance represents the average net movement of stocked coho, and seems to be insensitive to stocking density; however, because those fish which moved soon after stocking were killed at the fences immediately upstream and downstream of the stocking, this estimate of net movement is considered minimal. Maximum distances for individual fish moving after the fences had been removed were 1200 m upstream and 1950 m downstream.

There are practical advantages to reducing the number of stocking sites (i.e. increasing the distance between point plants). At one extreme, a single point plant at one location (e.g. a bridge) would be unlikely to provide an even distribution of fish, particularly in the upstream direction. At the other extreme, the distance of 230 m between sites is likely to be a conservative estimate, and an even distribution may be obtained at distances considerably exceeding this. In any case, the distance between sites should probably not exceed 500 m, the maximum average recorded for any single stocking group in Banon Creek (the low density group stocked in October).

5.3.3 Stocking Time and Density

In this section, four representative stocking strategies are compared. The comparison is made without regard to any impact of residual one-year-old coho from previous stockings or any impacts on resident cutthroat populations. The four stocking strategies under consideration are:

1. High density, early stocking (HE)
2. Low density, early stocking (LE)
3. High density, late stocking (HL)
4. Low density, late stocking (LL).

In the foregoing, high and low density refer to biomass rather than numbers per unit area, the term "early" to July stocking, and the term "late" to October stocking.

The following table summarizes the results obtained for July and October stockings in Banon Creek. Because of the unusual mortality among fish planted in Bush Creek in October, a mortality probably unrelated to the conditions of the experiment, only Banon Creek data are used here.

Strategy	% Survival	Smolts/m2
HE	5.2	0.09
LE	12.5	0.06
HL	26.2	0.16
LL	44.4	0.04

A second table provides comparisons of survival and smolt production for the four strategies under consideration.

Comparison	Best Survival	Best Smolt Production
HE x LE	LE	HE
HE x HL	HL	HL
HE x LL	LL	HE
LE x HL	HL	HL
LE x LL	LL	LE
HL x LL	LL	HL

Any of these four stocking strategies might be appropriate, depending on the objectives of the stocking program. For example, if the objective is to maximize the number of smolts produced per unit area of stream, one or the other of the two high density strategies would be appropriate. If, on the other hand, the primary objective is to maximize the number of smolts produced per fry stocked, one or the other of the two low density strategies would be appropriate. Where fry are abundant and the costs of production are low in relation to the expected benefits in increased catches in domestic, sports, and commercial fisheries, high density stockings might be favoured. Low density stocking might be favoured where fry are scarce (e.g. in attempting to supplement a failing population where the broodstock is very small), or where the costs of production are high.

With regard to time of stocking, survival is best for later stockings, whether at high or low densities. For low density stockings, smolt production is best for fish planted early. For high density stockings, smolt production is best for fish planted late.

Since, in most circumstances, the primary objective of a stocking program will be the production of smolts, high density stockings will often be preferred. Further, there may be definite advantages to early versus late stockings. Early fish are stocked after a shorter period of feeding and consequently require a much smaller commitment to facilities and food than late stocked fish. Early fish also take greater advantage of the productivity of the recipient stream. One possible disadvantage of early stocking, especially in unproductive streams, is that fish may grow very slowly, and have an extended freshwater life over a second summer and winter. Such fish may have adverse effects on subsequent stockings, a possibility discussed in the following section.

5.3.4 Effect of Other Juvenile Coho

Where hatchery produced coho fry are being superimposed on a population of one-year-old juveniles which will smolt the following spring, Mills' (1969) studies of Atlantic salmon suggest that survival of fry stocked at high densities may be depressed to the extent that smolt production from high and low density plantings is the same. Under these circumstances, there may be no benefit in terms of smolts produced from plantings at high density. This is a factor which has not been assessed in relation to coho salmon, but which should be considered.

Where extended freshwater residency is likely to occur, any potential problems can be avoided by either stocking fish late, at larger sizes, or by stocking them at two or three-year intervals to ensure that all coho from previous stockings have migrated seaward. When extended freshwater residency is a problem, but early fry are nevertheless planted annually, low density stockings may give results as good as those achieved by high density stockings.

5.3.5 Effects on Cutthroat Trout

The data suggest that isolated cutthroat trout populations are adversely affected by stocking coho fry. These adverse effects can be mitigated in several ways. With regard to stocking densities, coho should be stocked at low densities because these appear to have the least effect. With regard to stocking time, the data are equivocal.In Banon Creek, the effects on survival and production, though not growth, appear to have been greatest for the late stockings; however, these effects are not particularly representative of impacts on young-of-the-year trout. Overall, it would appear that spring stocking had the greatest adverse effect on cutthroat trout in Banon Creek, and fall stocking had the greatest adverse effect in Bush Creek.

The difference may lie in the high mortality and the presumably intense interspecific and intraspecific competition which occurred in the spring in Bush Creek, but not in Banon Creek. Because of the disparity of these results, general recommendations concerning stocking times which would protect cutthroat trout populations cannot be made. This problem requires further study.

Regardless of time or density, a policy of stocking coho continuously will lead to declines in, or even the elimination of, resident populations of cutthroat trout. Almost all of the potentially adverse effects can be mitigated, however, if stocking is rotated so that individual streams are stocked at intervals of four years or more. This interval, the approximate generation time of cutthroat trout, should allow sufficient time for trout populations to recover from the effects of stocking.

5.4 Comments on Study Design

Although the present study provides useful information on the effects of different stocking strategies on coho salmon and cutthroat trout production in isolated streams, a number of shortcomings in the experimental design clearly influenced interpretation of the results. These shortcomings, which should be remedied before future studies of this type are undertaken, are summarized here:

1. The history of the coho fry used in each stocking period differed considerably, making comparisons between stocking times difficult. Growth and survival, for example, may have been quite different if the fry used for each stocking had been reared under the same conditions. A control group should also have been maintained at the hatchery.

2. The range of stocking times was too narrow. Some unfed fry should have been included since they are likely to be, in many instances, the principal fry used in headwater stocking programs.

3. Fish captured during the first 20 to 30 days moving out of the section they were stocked in were killed. Where such movements were substantial, the survival estimates were minimal, since it is unlikely that all such fish would suffer complete mortality.

4. Movements out of each study reach during the winter were not considered. As shown for Banon Creek, this would have had a major effect on our survival estimates where the number of smolts estimated to be in the reservoir below the study reach was equal to 70% of the smolts taken moving downstream in the spring. Similar movements in Bush Creek may have also biased the survival estimates of fish in the July and August stockings.

5. By chance, there was a tributary to each study stream near the sections stocked in October. Survival of fish in the October stocking in Banon Creek was therefore probably greater than if there had been no tributary. In Bush Creek, in contrast, survival of fish stocked in October at low densities may have been lower than if they had had to overwinter in Bush Creek proper.

6. Initially, the main emphasis of the study was on the effect of various stocking strategies on the growth and survival of coho fry to smolting. It was therefore not considered necessary to weir the upper and lower ends of the control sections. Weiring the control sections, however, would have provided a useful index of cutthroat trout movements in unstocked areas with which to compare cutthroat trout movements in the experimental sections. As it was, cutthroat trout movements out of each experimental section were compared with movements of trout into each section from adjacent, unstocked areas.

7. Accurate estimates of cutthroat trout fry were not made until September in Bush Creek, and October in Banon Creek. As a result, the impact of coho stockings on cutthroat trout fry was not examined during the early stockings.

8. There were no estimates of the number of older cutthroat present in each section during the spring period. Densities at the beginning of this period were based on straight-line interpolations between estimates made during the previous fall (1980) and the following summer (1981). Since the

spring period was a time of rapid growth, differences in the survivorship curves of cutthroat trout at this time could have substantially affected production estimates, particularly in Emon Creek.

9. Short-term mortality due to handling was not evident. Long-term mortality was not assessed, however, and may have contributed to higher mortality among earlier stockings.

10. From the point-of-view of detecting systematic variables such as increased production upstream or downstream, the study may have been under-controlled. Although much more costly, randomizing the location of each experimental section within the study reaches (with at least one control for each stocking period) would have been a better design. At the very least, two control sections should probably have been used, one at the lower end and one at the upper end of each study reach.

6.0 ACKNOWLEDGEMENTS

The authors wish to acknowledge the technical assistance in the field of Bill Grant, Randy Stennis, Joel Parker, Ian Morton, Peter Withler, and Darlene Dobbs. Thanks are also due to Bill Grant for drafting the figures and to Joanne Tripp who typed and assembled the manuscript.

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Table 1. Habitat characteristics of Sections 1-10 in Banon Creek, 22-25 September 1980. S=sand/silt, G=gravel, R=rubble, B=boulder, Bd=bedrock.

Section No.	Length (m)	Width (m)		Wetted Area (m²)	Depth (m)	Velocity (m/s)
		Wet	Dry			
1	280	8.3	13.5	2324	0.30	0.13
2	205	9.7	13.9	1987	0.23	0.14
3	221	8.0	12.3	1768	0.23	0.22
4	208	7.1	13.9	1477	0.19	0.16
5	207	4.9	11.8	1014	0.26	0.23
6	205	8.8	12.1	1804	0.21	0.14
7	180	5.9	12.4	1062	0.23	0.22
8	200	6.2	14.1	1240	0.22	0.22
9	220	7.2	14.5	1584	0.26	0.19
10	120	8.3	13.4	996	0.21	0.18
Mean	214	7.4	13.2	1526	0.23	0.18

Continued

Table 1. Concluded

Section No.	% Substrate Composition S	G	R	B	Bd	Substrate Vegetation	% Erosion	% Cover	% Gradient
1	20.0	30.3	22.3	19.3	7.3	Lacking	23.7	50.7	1.76
2	12.0	20.5	41.0	24.0	2.5	Lacking	29.0	50.0	1.20
3	5.1	21.3	36.1	25.9	11.6	Lacking	36.8	49.1	1.41
4	12.6	28.9	21.0	25.0	12.5	Lacking	39.0	34.5	1.57
5	3.5	12.5	22.5	32.5	29.0	Little	22.5	64.5	2.98
6	15.9	25.5	37.7	20.9	0.0	Lacking	44.5	43.6	1.79
7	11.0	25.5	29.5	28.5	5.5	Little	26.5	61.5	1.94
8	10.5	40.0	34.5	15.0	0.0	Lacking	54.1	51.4	2.23
9	11.0	36.5	36.0	16.5	0.0	Lacking	34.0	55.4	2.43
10	7.1	28.0	37.1	25.7	2.1	Little	28.6	55.0	3.19
Mean	10.9	26.9	31.8	23.3	7.1	Lacking	33.9	51.6	2.05

Table 2. Habitat characteristics of Sections 1-10 in Bush Creek, 22-25 September 1980. S=sand/silt, G=gravel, R=rubble, B=boulder, Bd=bedrock.

Section No.	Length (m)	Width (m) Wet	Width (m) Dry	Wetted Area (m^2)	Depth (m)	Velocity (m/s)
1	200	5.3	11.2	1060	0.23	0.05
2	190	4.1	9.4	779	0.13	0.07
3	150	4.7	9.7	705	0.19	0.03
4	206	4.0	9.3	824	0.21	0.07
5	190	4.3	7.9	817	0.20	0.06
6	240	5.3	7.8	1272	0.28	0.06
7	200	4.3	8.4	860	0.20	0.05
8	200	4.5	9.4	900	0.25	0.04
9	180	4.4	7.9	792	0.18	0.02
10	120	3.4	9.7	408	0.16	0.02
Mean	195	4.4	9.1	842	0.20	0.05

Continued

Table 2. Concluded

Section No.	% Substrate Composition S	G	R	B	Bd	Substrate Vegetation	% Erosion	% Cover	% Gradient
1	12.3	35.4	21.8	25.9	4.6	Lacking	19.1	28.6	1.1
2	8.0	20.0	32.5	29.0	10.5	Little	22.5	51.5	1.4
3	10.0	15.0	30.0	23.8	21.2	Little	16.3	49.4	1.0
4	7.3	17.3	30.4	34.5	10.5	Little	38.6	57.3	3.0
5	15.0	22.5	37.0	24.0	1.5	Little	52.5	50.5	1.8
6	15.4	33.1	24.6	21.9	5.0	Lacking	60.4	55.0	2.3
7	27.5	26.0	21.5	19.0	6.0	Little	15.0	58.5	2.4
8	20.0	46.1	12.8	15.5	5.6	Lacking	35.0	56.7	0.8
9	17.0	31.5	30.0	19.5	2.0	Lacking	44.0	52.5	1.6
10	7.1	23.6	26.4	41.4	1.5	Little	21.4	42.1	3.1
Mean	14.0	27.0	26.7	25.5	6.8	Little	32.5	50.2	1.85

Table 3. Stream habitat attributes used in the Habitat Quality Index, the characteristics used to rate them, and their multiple regression correlation coefficients (R) from a multiple regression analysis of their relationship to trout standing crop. R values followed by an asterisk (*) are significantly different from zero at the $\alpha = 0.95$ level ($R = 0.378$ from Table A-30a, Dixon and Massey 1969). ADF = average daily flow for the water year, obtained from gauging station records, if available; CPF = average daily flow during August and the first half of September only, from gauging station records, if available; SAV = submerged aquatic vegetation, includes algae and moss growing on rocks. From Binns and Eiserman (1979).

Attribute	Symbol	R	Rating Characteristics				
			0 (worst)	1	2	3	4 (best)
Late summer stream flow	X_1	0.36	Inadequate to support trout (CPF <10% ADF)	Very limited: potential for trout support is sporadic (CPF 10-15% ADF)	Limited: CPF may severely limit trout stocking every few years (CPF 16-25% ADF)	Moderate: CPF may occasionally limit trout numbers (CPF 26-55% ADF)	Completely adequate: CPF very seldom limiting to trout (CPF> 55% ADF)
Annual stream flow variation	X_2	0.80*	Intermittent stream	Extreme fluctuation, but seldom dry; base flow very limited	Moderate fluctuation, but never dry; base flow occupies up to two-thirds of channel	Small fluctuation; base flow stable, occupies most of channel	Little or no fluctuation
Maximum stream temp (C)	X_3	0.28	<6 or >26.4	6-8 or 24.2-26.3	8.1-10.3 or 21.5-24.1	10.4-12.5 or 18.7-21.4	12.6-18.6

Continued

Table 3. Concluded

Attribute	Symbol	R	Rating Characteristics				
			0 (worst)	1	2	3	4 (best)
Nitrate nitrogen (mg/L)	X_4	0.69*	<0.01 or >2.0	0.01–0.04 or 0.91–2.0	0.05–0.09 or 0.51–0.90	0.10–0.14 or 0.26–0.50	0.15–0.25
Cover (%)[b]	X_5	0.55*	<10	10–25	26–40	41–55	>55
Eroding banks (%)[c]	X_6	0.45*	75–100	50–74	25–49	10–24	0–9
Substrate vegetation	X_7	0.44*	lacking	little	Occasional patches	Frequent patches	Well developed and abundant
Water velocity (cm/sec)[d]	X_8	0.38*	<8 or >122	8–15.4 or 106.6–122	15.5–30.3 or 91.4–106.5	30.4–45.5 or 76.1–91.3	45.6–76
Stream width (m)	X_9	0.38*	<0.6 or >46	0.6–2.0 or 23–46	2.1–3.5 or 15.1–22.9	3.6–5.3 or 6.7–15	5.4–6.6

Table 4. Coho stocking times and stocking densities in Banon Creek and Bush Creek, 19 July to 8 October 1980.

Section No.	Date Stocked	Section Length (m)	Wetted Area (m^2)		No. Coho Stocked	Initial Density		Low Flow Density	
			At Stocking	22-25 Sept		No./m^2	Wt(g)/m^2	No./m^2	Wt(g)/m^2
Banon 1	21 July	280	2200	2324	4000	1.82	2.62	1.72	2.41
Banon 2	21 July	205	1700	1987	1800	1.06	1.52	0.91	1.27
Banon 3	21 July	220	2160	1473	750	0.35	0.50	0.48	0.67
Banon 4	30 Aug	210	1070	1477	1500	1.40	2.54	1.02	1.84
Banon 5	30 Aug	205	1025	1014	850	0.83	1.50	0.84	1.51
Banon 6	30 Aug	205	1720	1804	475	0.28	0.50	0.26	0.47
Banon 7	8 Oct	180	2000	1062	650	0.32	2.53	0.61	4.76
Banon 8	8 Oct	200	2100	1240	410	0.20	1.52	0.33	2.57
Banon 9	8 Oct	220	2300	1584	150	0.06	0.51	0.09	0.70
Bush 1	19 July	200	1000	1060	1750	1.75	2.52	1.65	2.31
Bush 2	19 July	190	1240	779	1350	1.09	1.57	1.73	2.42
Bush 3	19 July	150	765	705	275	0.36	0.52	0.39	0.55
Bush 4	30 Aug	205	560	824	750	1.34	2.37	0.91	1.64
Bush 5	30 Aug	190	690	817	550	0.80	1.41	0.67	1.21
Bush 6	30 Aug	240	1100	1272	300	0.27	0.48	0.24	0.43
Bush 7	8 Oct	200	1120	860	360	0.32	2.50	0.42	3.28
Bush 8	8 Oct	200	1340	900	260	0.19	1.51	0.29	2.26
Bush 9	8 Oct	180	1170	900	75	0.06	0.50	0.08	0.62

Table 5. Schedule of survey-removal estimates in Banon Creek, June 1980 to July 1981.

Sections 1 to 3 (Stocked 21 July)	Sections 4 to 6 (Stocked 30 Aug)	Sections 7 to 9 (Stocked 8 Oct)	Control (Unstocked)
1980			
10–13 July			23 July
14–16 Aug	24–25 Aug		5 Sept
12–17 Sept	24–25 Sept	2 Oct	25 Sept
15–16 Oct	17–18 Oct	27–28 Oct	22 Oct
1981			
13–14 April	25–27 March	23–25 March	14 April
2–3 July	3–5 July	6 July	6 July

Table 6. Schedule of survey-removal estimates in Bush Creek, June 1980 to July 1981.

Sections 1 to 3 (Stocked 19 July)	Sections 4 to 6 (Stocked 30 Aug)	Sections 7 to 9 (Stocked 8 Oct)	Control (Unstocked)
1980			
25-29 June			1 July
12-14 Aug	23 Aug		22 Aug
8-9 Sept	20-22 Sept	2 Oct	22 Sept
11-14 Oct	20-22 Oct	29-30 Oct	21 Oct
1981			
5-8 March	9-13 March	17-19 March	20 March
24-25 March	26-29 March	30 June-1 July	1 July

Table 7. Stream habitat ratings and predicted fish standing crop for Sections 1-10 in Banon Creek.

Habitat Attribute	Model Symbol	Section No. 1	2	3	4	5	6	7	8	9	10	All Sections Combined
Late Summer Stream Flow	X_1	1	1	1	1	1	1	1	1	1	1	1
Annual Stream Flow Variation	X_2	1	1	1	1	1	1	1	1	1	1	1
Maximum Summer Stream Temperature	X_3	4	4	4	4	4	4	4	4	4	4	4
Nitrate Nitrogen	X_4	3	3	3	3	3	3	3	3	3	3	3
Cover	X_5	3	3	3	2	4	3	4	3	4	4	3
Eroding Stream Banks	X_6	3	2	2	2	3	2	2	1	2	2	2
Substrate Vegetation	X_7	0	0	0	0	1	0	1	0	0	0	0
Water Velocity	X_8	2	2	3	2	3	3	3	3	3	4	3
Stream Width	X_9	3	3	3	3	3	3	3	3	3	3	3
Predicted Standing Crop (g/m^2)	$\hat{Y}$	0.5	0.5	0.5	0.4	6.1	0.5	5.6	0.4	0.5	0.5	0.5

Table 8. Stream habitat ratings and predicted fish standing crop for Sections 1-10 in Bush Creek.

Habitat Attribute	Model Symbol	Section No.										All Sections Combined
		1	2	3	4	5	6	7	8	9	10	
Late Summer Stream Flow	X_1	1	1	1	1	1	1	1	1	1	1	1
Annual Stream Flow Variation	X_2	1	1	1	1	1	1	1	1	1	1	1
Maximum Summer Stream Temperature	X_3	4	4	4	4	4	4	4	4	4	4	4
Nitrate Nitrogen	X_4	3	3	3	3	3	3	3	3	3	3	3
Cover	X_5	2	3	3	4	3	3	4	4	3	3	3
Eroding Stream Banks	X_6	3	3	3	2	1	1	3	2	2	3	2
Substrate Vegetation	X_7	0	1	1	1	1	0	1	0	0	1	1
Water Velocity	X_8	1	1	1	1	1	3	1	1	0	0	1
Stream Width	X_9	3	3	3	3	3	3	3	3	3	2	3
Predicted Standing Crop (g/m²)	$\hat{Y}$	0.5	2.9	2.9	2.9	2.4	0.4	3.7	0.5	0.5	0.5	2.7

Table 9. Coho salmon and cutthroat trout movements in Sections 1 to 9 of Banon Creek during the first 20 to 30 days after stocking. The number in brackets is the number of fish captured expressed as a percentage of the total number of fish initially present.

Section No.	Time Period	Coho		YOY Cutthroat		Older Cutthroat	
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
1	21 July-19 Aug	40(1.0)	80(2.0)	0(ND)	72(ND)	2(1.3)	0(0.0)
2	21 July-19 Aug	22(1.2)	28(1.6)	0(ND)	3(ND)	11(11.2)	4(4.1)
3	21 July-19 Aug	15(2.0)	7(0.9)	1(ND)	3(ND)	6(7.1)	5(5.9)
4	30 Aug -19 Sept	131(8.7)	8(0.5)	2(ND)	11(ND)	1(0.6)	1(0.6)
5	30 Aug -19 Sept	8(0.9)	24(2.8)	0(ND)	15(ND)	0(0.0)	1(1.1)
6	30 Aug -19 Sept	72(15.2)	7(1.5)	0(ND)	2(ND)	0(0.0)	1(0.9)
7	8 Oct -31 Oct	1(0.2)	1(0.2)	2(2.3)	1(1.1)	1(0.9)	2(1.8)
8	8 Oct -31 Oct	127(31.0)	0(0.0)	1(1.9)	1(1.9)	1(0.9)	2(1.8)
9	8 Oct -31 Oct	61(41.0)	0(0.0)	4(4.3)	1(1.1)	1(1.3)	0(0.0)
Total		467	155	10	108	23	16

ND = No Data Percentages could not be calculated because fish were too small to be accurately censused.

Table 10. Coho salmon and cutthroat trout movement in Sections 1 to 9 of Bush Creek during the first 20 to 30 days after stocking. The number in brackets is the number of fish captured expressed as a percentage of the total number of fish initially present.

Section No.	Time Period	Coho		YOY Cutthroat		Older Cutthroat	
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
1	19 July-18 Aug	28(1.6)	36(2.1)	1(ND)	2(ND)	1(1.1)	1(1.1)
2	19 July-18 Aug	148(11.0)	58(4.3)	6(ND)	1(ND)	5(6.1)	0(0.0)
3	19 July-18 Aug	65(23.6)	7(2.5)	6(ND)	0(ND)	5(4.9)	3(2.9)
4	30 Aug -19 Sept	57(7.6)	11(1.5)	0(0.0)	2(1.3)	1(0.4)	0(0.0)
5	30 Aug -19 Sept	178(32.4)	11(2.0)	1(1.4)	0(0.0)	7(4.7)	1(0.7)
6	30 Aug -19 Sept	10(3.3)	10(3.3)	0(0.0)	0(0.0)	2(2.1)	0(0.0)
7	8 Oct -31 Oct	16(4.4)	0(0.0)	1(0.4)	0(0.0)	0(0.0)	0(0.0)
8	8 Oct -31 Oct	33(12.7)	0(0.0)	2(0.8)	0(0.0)	0(0.0)	0(0.0)
9	8 Oct -31 Oct	3(4.0)	1(1.3)	3(1.2)	0(0.0)	2(2.0)	0(0.0)
Total		538	134	20	5	23	5

ND = No Data Percentages could not be calculated because fish were too small to be accurately censused.

Table 11. Distribution of coho salmon fry planted 19-21 July and 30 August and recaptured 15-30 October 1980.

Stream	Stocking Date	No. Fish Examined	Extent of Movement - Number of Sections										
			Downstream						Upstream				
			5	4	3	2	1	0	1	2	3	4	5
Banon	21 July	650	0	0	0	0	0	645	5	0	0	0	0
Banon	30 August	452	48	0	0	22	6	374	2	0	0	0	0
Bush	19 July	349	0	0	0	0	0	344	5	0	0	0	0
Bush	30 August	153	0	0	0	0	0	153	0	0	0	0	0

Table 12. Seasonal variations in the number of coho salmon captured moving downstream in Banon Creek, 9 March to 23 June 1981, according to the time and density they were originally stocked at. H=high density, M=medium density, L=low density.

	Stocking Time and Density									
	July 21			August 30			October 8			
Date	H	M	L	H	M	L	H	M	L	Total
9-31 March	0	0	1	2	0	0	1	0	0	4
1-10 April	42	21	16	15	5	7	2	1	0	109
11-20 April	6	5	4	7	3	0	1	1	0	27
21-30 April	0	1	1	0	0	0	4	0	0	6
1-10 May	1	1	0	1	5	0	9	1	0	18
11-21 May	35	18	13	18	22	9	32	16	7	170
21-31 May	68	33	22	60	49	35	86	60	32	445
1-10 June	41	25	31	53	27	24	33	21	20	285
11-23 June	5	1	3	7	11	3	1	4	2	37
Total	198	105	91	163	122	78	169	114	61	1101

Table 13. Seasonal variations in the number of coho salmon captured moving downstream in Bush Creek, 9 March to 11 June 1981, according to the time and density they were originally stocked at. H=high density, M=medium density, L=low density.

	Stocking Time and Density									
	July 19			August 30			October 8			
Date	H	M	L	H	M	L	H	M	L	Total
9-31 March	1	1	1	0	0	0	0	0	0	3
1-10 April	0	0	1	0	0	0	0	0	0	1
11-20 April	1	1	2	1	3	1	3	0	0	12
21-30 April	10	7	2	1	3	4	20	14	1	62
1-10 May	31	7	10	19	13	12	16	19	1	128
11-20 May	45	29	20	22	18	11	51	21	1	216
21-31 May	29	24	15	23	10	19	35	6	1	162
1-11 June	2	0	0	2	0	5	2	1	0	12
Total	119	69	51	68	47	52	127	61	4	598

Table 14. Variations in the number of cutthroat trout trapped at the lower end of the Banon and Bush Creek study areas, 4 March to 30 June, 1981.

Date	Banon Creek		Bush Creek
	Upstream	Downstream	Downstream
4-31 March	3	6	1
1-10 April	1	7	0
11-20 April	0	9	10
21-30 April	0	11	50
1-10 May	3	31	25
11-20 May	1	73	25
21-31 May	0	69	5
1-10 June	0	63	5
11-20 June	0	48	3
21-30 June	0	34	1
Total	8	351	125

Table 15. Seasonal variations in the number of coho salmon juveniles present in the Experimental Sections of Banon Creek, 1980 and 1981. Numbers in brackets are 95% confidence limits.

Stocking Time	Number Stocked	Section No.	1980 Survey Removal Estimates			1981 Petersen Mark Recapture Estimates	1981 Coho Smolt Trapping
			14-16 Aug	12-17 Sept	15-16 Oct	13-14 April	
21 July	4000	1	955 (±1175)	765 (±389)	970 (±373)	305 (217-443)	198
21 July	1800	2	1145 (± 544)	601 (±413)	585 (±207)	118 (75-197)	105
21 July	750	3	285 (± 134)	253 (±129)	268 (±116)	158 (95-279)	91
				20-22 Sept	20-22 Oct	9-13 March	
30 August	1500	4	-	789 (±283)	446 (± 76)	306 (216-450)	163
30 August	850	5	-	655 (±227)	297 (± 97)	206 (146-302)	122
30 August	475	6	-	164 (±119)	166 (± 36)	111 (77-167)	78
					27-28 Oct	23-25 March	
8 October	650	7	-	-	410 (±328)	222 (161-316)	169
8 October	410	8	-	-	No Data	110 (72-174)	114
8 October	150	9	-	-	125 (±191)	112 (62-223)	61

Table 16. Seasonal variations in the number of coho salmon juveniles present in the Experimental Sections of Bush Creek, 1980 and 1981. Numbers in brackets are 95% confidence limits.

Stocking Time	Number Stocked	Section No.	1980 Survey Removal Estimates			1981 Petersen Mark Recapture Estimates	1981 Coho Smolt Trapping
			12–14 Aug	8–9 Sept	11–14 Oct	5–8 March	
19 July	1750	1	734 (±287)	494 (±185)	398 (± 81)	368 (271–490)	119
19 July	1350	2	473 (± 94)	426 (±154)	270 (±100)	210 (134–315)	69
19 July	275	3	53 (± 50)	108 (± 13)	113 (± 79)	135 (70–237)	51
				20–22 Sept	20–22 Oct	9–13 March	
30 August	750	4	-	261 (± 69)	144 (± 14)	160 (99–272)	68
30 August	550	5	-	198 (± 87)	192 (± 87)	171 (91–349)	47
30 August	300	6	-	45 (± 59)	43 (± 47)	84 (49–157)	52
					29–30 Oct	17–19 March	
8 October	360	7	-	-	256 (±311)	256 (183–371)	127
8 October	260	8	-	-	287 (±197)	153 (96–255)	61
8 October	75	9	-	-	88 (± 28)	No Data	4

Table 17. Variations in density (N/m^2), % survival, and mortality rates (Z) for coho salmon stocked at different times and densities in Banon Creek.

Section No.	Date Stocked	Density (N/m^2)				% Survival				
		Initial	31 Oct	1 March	Smolt Stage	To 31 Oct	31 Oct- 1 March	1 March- Smolting	Overall	Z
1	21 July	1.72	0.29	0.14	0.09	16.9	48.3	64.3	5.2	3.313
2	21 July	0.91	0.21	0.08	0.05	23.1	38.1	62.5	5.5	3.259
3	21 July	0.48	0.16	0.10	0.06	33.3	62.5	60.0	12.5	2.335
4	30 Aug	1.02	0.30	0.24	0.11	29.4	80.0	45.8	10.8	2.863
5	30 Aug	0.84	0.28	0.22	0.12	33.3	78.6	54.5	14.3	2.501
6	30 Aug	0.26	0.08	0.07	0.04	30.8	87.5	57.1	15.4	2.406
7	8 Oct	0.61	0.38	0.22	0.16	62.3	57.9	72.7	26.2	1.994
8	8 Oct	0.33	0.24	0.10	0.09	72.7	41.7	90.0	27.3	1.936
9	8 Oct	0.09	0.08	0.07	0.04	88.9	87.5	57.1	44.4	1.208
Mean		0.70	0.22	0.14	0.08	43.4	64.7	68.7	18.0	2.424

Table 18. Variations in density (N/m^2), % survival, and mortality rates (Z) for coho salmon stocked at different times and densities in Bush Creek.

Section No.	Date Stocked	Density (N/m^2)				% Survival				
		Initial	31 Oct	1 March	Smolt Stage	To 31 Oct	31 Oct- 1 March	1 March- Smolting	Overall	Z
1	19 July	1.65	0.37	0.35	0.11	22.4	94.6	31.4	6.7	3.032
2	19 July	1.73	0.35	0.27	0.09	20.2	77.1	33.0	5.2	3.310
3	19 July	0.39	0.16	0.16	0.07	43.2	100.0	43.7	17.9	1.923
4	30 Aug	0.91	0.19	0.18	0.08	20.9	94.7	44.0	8.8	3.125
5	30 Aug	0.67	0.22	0.21	0.06	32.8	95.5	28.6	8.9	3.101
6	30 Aug	0.24	0.05	0.05	0.04	20.8	100.0	80.0	16.7	2.303
7	8 Oct	0.42	0.30	0.30	0.15	71.4	100.0	50.0	35.7	1.534
8	8 Oct	0.29	0.28	0.19	0.07	96.6	67.9	36.8	24.0	2.118
9	8 Oct	0.08	0.08	ND	0.004	100.0	ND	ND	5.0	4.463
Mean		0.71	0.22	0.21	0.06	47.6	91.2	38.6	14.3	2.832

ND = No Data, probably very low

Table 19. Estimates of the number of cutthroat trout (±2SD, 95% CL) from the 1980 year class in each Section of Banon Creek, September 1980 to July 1981. Exact sampling periods are summarized in Table 3.

Section No.	Sampling Period		
	1980		1981
	12-17 Sept	15-16 Oct	2-3 July
1	201±91	104±41	76± 2
2	131±54	67±20	45±21
3	176±22	92±36	94±26
	20-22 Sept	20-22 Oct	26-29 June
4	223±38	129±49	72±53
5	173±52	114± 5	54± 8
6	135±47	141±24	53±14
	2 Oct	27-28 Oct	6 July
7	73± 9	144±89	38± 1
8	35±13	100±15	54±30
9	80±26	180±43	77±54
	25 Sept	22 Oct	6 July
10	30	36	52

Table 20. Estimates of the number of cutthroat trout (±2SD, 95% CL) from the 1980 year class in each Section of Bush Creek, August 1980 to June 1981. Exact sampling periods are summarized in Table 2.

Section No.	Sampling Period			
	1980			1981
	10-14 Aug	8-9 Sept	11-14 Oct	24-25 June
1	115±13	128± 38	106± 65	85± 43
2	143±12	141± 3	82± 12	91± 3
3	80±35	59± 16	73± 16	66± 15
	23 Aug	20-22 Sept	20-22 Oct	26-29 June
4	162±91	115± 43	97± 57	75± 3
5	75±26	66± 30	52± 7	38± 18
6	90±55	123± 38	124± 28	90± 12
		2 Oct	29-30 Oct	1 July
7	-	281±172	264± 17	97± 43
8	-	254±184	228±124	164±129
9	-	253± 62	250± 85	106± 39
	22 Aug	22 Sept	21 Oct	1 July
10	84	57	43	65

Table 21. Variations in density (N/m^2), survival (%), and mortality rates (Z) for cutthroat trout fry in Banon and Bush Creek, 8 October 1980 to 10 June 1981.

Section No.	Banon Creek Density (N/m^2) 8 Oct	Banon Creek Density (N/m^2) 10 June	Banon Creek % Survival	Banon Creek Z	Bush Creek Density (N/m^2) 8 Oct	Bush Creek Density (N/m^2) 10 June	Bush Creek % Survival	Bush Creek Z
1	0.06	0.03	50.0	1.033	0.10	0.08	80.0	0.332
2	0.04	0.02	50.0	1.033	0.11	0.12	109.1	0.000
3	0.07	0.05	71.4	0.501	0.10	0.09	90.0	0.157
4	0.12	0.05	41.7	1.304	0.13	0.09	69.2	0.548
5	0.13	0.06	46.2	1.152	0.07	0.05	71.4	0.501
6	0.08	0.03	37.5	1.461	0.10	0.07	70.0	0.531
7	0.08	0.05	62.5	0.700	0.32	0.13	40.6	1.342
8	0.04	0.05	120.0	0.00	0.27	0.19	70.4	0.524
9	0.07	0.05	71.4	0.501	0.31	0.15	48.4	1.081
Mean	0.07	0.04	57.1	0.854	0.16	0.12	75.0	0.557
10 (Control)	0.03	0.05	166.7	0.00	0.12	0.15	125.0	0.000

Table 22. Survey-removal estimates of cutthroat trout numbers (±2SD) in Banon Creek 10 July 1980 to 6 July 1981.

Section No.	Year Class	Sampling Dates				
		10-13 July	14-16 Aug	12-17 Sept	15-16 Oct	2-3 July
1	1979	135 ± 80	51 ± 2	67 ± 55	33 ± 33	43 ± 61
	1978	17 ± 8	13 ± 5	21 ± 16	17 ± 24	5 ± 7
	1977	6 ± 8	0	0	0	0
2	1979	68 ± 29	41 ± 3	72 ± 18	30 ± 4	33 ± 5
	1978	29 ± 1	26 ± 1	46 ± 33	16 ± 13	11 ± 5
	1977	10 ± 0	6 ± 1	11 ± 6	4 ± 6	0
3	1979	66 ± 23	34 ± 3	72 ± 39	60 ± 14	29 ± 19
	1978	12 ± 17	22 ± 9	28 ± 19	8 ± 12	4 ± 5
	1977	12 ± 5	7 ± 10	12 ± 18	13 ± 6	0
			24-25 Aug	24-25 Sept	17-18 Oct	3-5 July
4	1979		91 ± 19	64 ± 14	43 ± 22	38 ± 54
	1978		48 ± 10	34 ± 6	23 ± 3	0
	1977		37 ± 6	26 ± 5	11 ± 4	0
5	1979		52 ± 5	43 ± 19	28 ± 6	39 ± 9
	1978		41 ± 19	31 ± 2	43 ± 39	0
	1977		3 ± 5	4 ± 6	16 ± 22	0

Continued

Table 22. Concluded

Section No.	Year Class	Sampling Dates				
			24-25 Aug	24-25 Sept	17-18 Oct	3-5 July
6	1979		67 ± 43	46 ± 17	46 ± 36	18 ± 5
	1978		29 ± 10	21 ± 1	25 ± 16	11 ± 5
	1977		28 ± 29	18 ± 16	4 ± 5	0
				2 Oct	27-28 Oct	6 July
7	1979			48 ± 12	67 ± 16	37 ± 8
	1978			51 ± 11	38 ± 20	17 ± 11
	1977			10 ± 4	4 ± 6	0
8	1979			49 ± 9	100 ± 55	14 ± 10
	1978			46 ± 14	46 ± 23	7 ± 0
	1977			16 ± 22	18 ± 14	0
9	1979			46 ± 0	49 ± 13	77 ± 5
	1978			31 ± 0	24 ± 23	4 ± 6
	1977			0	4 ± 5	0
		23 July	5 Sept	25 Sept	22 Oct	6 July
10	1979	45	46	22	24	52
	1978	31	31	12	20	25
	1979	16	13	4	6	6

Table 23. Survey-removal estimates of cutthroat trout numbers (±2SD) in Bush Creek, 25 June 1980 to 1 July 1981.

Section No.	Year Class	Sampling Dates				
		25-29 June	12-14 Aug	8-9 Sept	11-14 Oct	24-25 June
1	1979	50 ± 41	19 ± 27	41 ± 58	41 ± 49	24 ± 5
	1978	54 ± 18	43 ± 16	27 ± 29	34 ± 39	20 ± 19
	1977	4 ± 6	15 ± 10	10 ± 14	10 ± 5	0
2	1979	50 ± 38	44 ± 30	19 ± 9	3 ± 4	20 ± 18
	1978	26 ± 17	24 ± 13	13 ± 9	16 ± 4	8 ± 11
	1977	15 ± 22	6 ± 9	0	0	0
3	1979	68 ± 18	52 ± 10	56 ± 16	58 ± 10	39 ± 9
	1978	40 ± 12	31 ± 12	28 ± 3	33 ± 9	18 ± 18
	1977	5 ± 8	10 ± 6	10 ± 7	10 ± 7	0
			23 Aug	20-22 Sept	20-22 Oct	26-29 June
4	1979		184 ± 7	110 ± 9	62 ± 30	53 ± 45
	1978		90 ± 30	54 ± 20	73 ± 26	11 ± 15
	1977		14 ± 20	8 ± 11	4 ± 6	0
5	1979		73 ± 65	73 ± 75	52 ± 73	35 ± 14
	1978		42 ± 8	45 ± 8	28 ± 0	19 ± 0
	1977		34 ± 10	25 ± 27	31 ± 45	0

Continued

Table 23. Continued

Section No.	Year Class	Sampling Dates			
		23 Aug	20-22 Sept	20-22 Oct	26-29 June
6	1979	26 ± 37	32 ± 45	32 ± 34	33 ± 0
	1978	52 ± 70	52 ± 51	40 ± 23	20 ± 6
	1977	13 ± 18	16 ± 23	32 ± 11	4 ± 4
	1976	3 ± 5	4 ± 6	4 ± 6	0
			2 Oct	29-30 Oct	30 June
7	1979		148 ± 29	144 ± 68	38 ± 7
	1978		83 ± 24	55 ± 0	38 ± 13
	1977		47 ± 6	45 ± 3	0
8	1979		74 ± 59	90 ± 43	59 ± 37
	1978		56 ± 2	63 ± 60	28 ± 11
	1977		31 ± 14	40 ± 28	3 ± 5
	1976			3 ± 5	0
9	1979		53 ± 29	58 ± 39	50 ± 15
	1978		37 ± 34	35 ± 28	16 ± 14
	1977		9 ± 13	6 ± 9	
	1976		3 ± 4	3 ± 4	

Continued

Table 23. Concluded

Section No.	Year Class	Sampling Dates				
		1 July	22 Aug	22 Sept	21 Oct	1 July
10	1979	49	31	12	11	65
	1978	8	6	8	6	24
	1977	3	3	3	3	9
	1976	2				

Table 24. Variations in density (N/m^2) and survival (%) among older cutthroat trout in the experimental and control Sections of Banon and Bush creeks, from the time each Section was stocked with coho in 1980 to 10 June, 1981.

	Banon Creek				Bush Creek			
Section No.	At Stocking	10 June	% Survival	% Difference from Control	At Stocking	10 June	% Survival	% Difference from Control
1	0.057	0.021	36.8	+ 0.9	0.087	0.044	50.5	+10.3
2	0.049	0.023	46.9	+11.0	0.107	0.035	32.7	- 7.5
3	0.048	0.021	43.8	+ 7.9	0.148	0.087	58.8	+18.6
4	0.112	0.028	25.0	-11.7	0.316	0.087	27.5	-30.4
5	0.092	0.043	46.7	+10.0	0.180	0.071	39.4	-18.5
6	0.065	0.018	27.7	- 9.0	0.074	0.047	63.5	+ 5.6
7	0.102	0.056	54.9	-20.1	0.313	0.101	32.3	-67.7
8	0.099	0.029	29.3	-45.7	0.187	0.108	57.7	-42.3
9	0.049	0.051	104.1	+29.1	0.117	0.085	72.6	-27.4
Mean	0.075	0.032	46.1	- 3.1	0.170	0.074	48.3	-17.7
10 (Control)								
21 July	0.092	0.033	35.9		0.127	0.051	40.2	
30 Aug	0.090	0.033	36.7		0.088	0.051	57.9	
8 Oct	0.044	0.033	75.0		0.051	0.051	100.0	

Table 25. Seasonal variations in mean weight (g,±2SE) for coho salmon stocked at different times and densities in Banon Creek, 21 July 1980 to 23 July 1981.

Section No.	Stocking Time-Density	Sampling Periods					
		1980				1981	
		21 July	14-16 Aug	12-17 Sept	15-16 Oct	13-14 April	9 March-23 June
1	21 July-High	1.4±0.2 (N=25)	2.2±0.3 (N=30)	2.3±0.2 (N=66)	2.4±0.2 (N=60)	6.4±1.2 (N=29)	8.9±0.3 (N=191)
2	21 July-Medium	1.4±0.2 (N=25)	2.1±0.3 (N=30)	2.3±0.2 (N=64)	2.3±0.2 (N=60)	4.4±1.2 (N=9)	8.8±0.6 (N=101)
3	21 July-Low	1.4±0.2 (N=25)	2.1±0.3 (N=29)	2.7±0.2 (N=59)	2.9±0.3 (N=55)	4.3±0.9 (N=20)	8.2±0.5 (N=87)
			30 Aug	20-22 Sept	20-22 Oct	9-13 March	27 March-23 June
4	30 Aug-High		1.8±0.2 (N=44)	2.5±0.2 (N=60)	2.5±0.2 (N=58)	4.9±0.5 (N=49)	7.5±0.3 (N=159)
5	30 Aug-Medium		1.8±0.2 (N=44)	2.3±0.2 (N=60)	2.7±0.2 (N=53)	5.9±0.7 (N=30)	8.3±0.4 (N=119)
6	30 Aug-Low		1.8±0.2 (N=44)	2.9±0.2 (N=60)	2.9±0.2 (N=47)	5.1±1.0 (N=17)	8.9±0.5 (N=77)
				8 Sept	27-28 Oct	23-25 March	27 March-19 June
7	8 Oct-High			7.8±0.5 (N=50)	6.7±0.6 (N=53)	8.2±0.7 (N=33)	10.4±0.4 (N-167)
8	8 Oct-Medium			7.8±0.5 (N=50)	7.0±0.6 (N=27)	7.3±0.6 (N=4)	10.6±0.4 (N=113)
9	8 Oct-Low			7.8±0.5 (N=50)	7.5±0.5 (N=39)	10.4±1.4 (N=12)	10.9±0.6 (N=61)

Table 26. Seasonal variations in mean fork length (mm,±2SE) for coho salmon stocked at different times and densities in Banon Creek, 21 July 1980 to 23 June 1981.

Section No.	Stocking Time-Density	Sampling Periods					
		1980				1981	
		21 July	14-16 Aug	12-17 Sept	15-16 Oct	13-14 April	9 March-23 June
1	21 July-High	49.9±1.9 (N=25)	54.8±2.2 (N=30)	57.3±1.7 (N=66)	60.2±1.7 (N=60)	80.1±5.0 (N=29)	93.4±1.3 (N=191)
2	21 July-Medium	49.9±1.9 (N=25)	54.7±1.9 (N=30)	56.4±1.5 (N=64)	59.1±1.7 (N=60)	70.9±5.8 (N=9)	92.6±1.8 (N=101)
3	21 July-Low	49.9±1.9 (N=25)	55.2±1.7 (N=29)	61.4±1.4 (N=59)	63.1±1.7 (N=55)	69.0±4.6 (N=20)	90.8±1.8 (N=87)
			30 Aug	20-22 Sept	20-22 Oct	9-13 March	27 March-23 June
4	30 Aug-High		57.2±1.3 (N=44)	60.1±1.4 (N=60)	61.4±1.4 (N=58)	71.8±2.5 (N=44)	87.6±1.4 (N=159)
5	30 Aug-Medium		57.2±1.3 (N=44)	59.0±1.5 (N=60)	61.4±1.4 (N=53)	76.9±2.8 (N=30)	91.5±1.5 (N=119)
6	30 Aug-Low		57.2±1.3 (N=44)	62.1±1.3 (N=46)	62.9±1.7 (N=47)	74.8±4.3 (N=17)	93.7±1.7 (N=77)
				8 Sept	27-28 Oct	23-25 March	27 March-19 June
7	8 Oct-High			85.6±2.0 (N=50)	82.7±2.6 (N=53)	87.2±2.6 (N=33)	100.2±1.2 (N=167)
8	8 Oct-Medium			85.6±2.0 (N=50)	84.3±2.7 (N=27)	84.3±4.7 (N=4)	100.8±1.3 (N=113)
9	8 Oct-Low			85.6±2.0 (N=50)	86.7±1.9 (N=39)	93.7±4.2 (N=12)	102.3±1.9 (N=61)

Table 27. Seasonal variations in mean weight (g/±2SE) for coho salmon stocked at different times and densities in Bush Creek, 19 July 1980 to 11 June 1981.

Section No.	Stocking Time-Density	Sampling Periods					
		1980				1981	
		19 July	10-14 Aug	8-9 Sept	11-14 Oct	5-8 March	9 March-11 June
1	19 July-High	1.4±0.2 (N=25)	1.4±0.1 (N=89)	2.0±0.2 (N=62)	2.8±0.2 (N=60)	2.8±0.4 (N=48)	7.5±0.4 (N=119)
2	19 July-Medium	1.4±0.2 (N=25)	1.4±0.1 (N=30)	1.9±0.2 (N=61)	2.4±0.1 (N=57)	3.9±0.4 (N=30)	7.0±0.5 (N=69)
3	19 July-Low	1.4±0.2 (N=25)	2.1±0.2 (N=28)	2.3±0.2 (N=55)	3.1±0.3 (N=43)	4.2±0.5 (N=23)	8.0±0.5 (N=51)
			30 Aug	20-22 Sept	20-22 Oct	9-13 March	11 April-9 June
4	30 Aug-High		1.8±0.2 (N=44)	2.1±0.2 (N=55)	2.4±0.2 (N=48)	4.0±0.3 (N=35)	6.9±0.3 (N=68)
5	30 Aug-Medium		1.8±0.2 (N=44)	2.3±0.2 (N=57)	2.7±0.2 (N=52)	4.3±0.3 (N=34)	7.7±0.5 (N=47)
6	30 Aug-Low		1.8±0.2 (N=44)	2.5±0.3 (N=15)	2.5±0.3 (N=38)	5.7±0.8 (N=12)	7.7±0.6 (N=52)
				8 Oct	29-30 Oct	17-19 March	12 April-5 June
7	8 Oct-High			7.8±0.5 (N=50)	6.8±0.5 (N=43)	9.5±0.6 (N=51)	14.7±0.8 (N=127)
8	8 Oct-Medium			7.8±0.5 (N=50)	7.0±0.5 (N=60)	10.0±0.6 (N=30)	19.8±1.6 (N=61)
9	8 Oct-Low			7.8±0.5 (N=50)	7.0±0.5 (N=39)	No Data	18.2±8.0 (N=4)

Table 28. Seasonal variations in mean fork length (mm,±2SE) for coho salmon stocked at different times and densities in Bush Creek, 19 July 1980 to 11 June 1981.

Section No.	Stocking Time-Density	Sampling Periods					
		1980				1981	
		19 July	10-14 Aug	8-9 Sept	11-14 Oct	5-8 March	9 March-11 June
1	19 July-High	49.9±1.9 (N=25)	50.9±1.0 (N=89)	55.9±1.4 (N=62)	60.6±1.3 (N=60)	65.7±2.3 (N=48)	87.9± 1.7 (N=119)
2	19 July-Medium	49.9±1.9 (N=25)	51.4±1.7 (N=30)	56.1±1.5 (N=61)	58.6±1.2 (N=57)	66.2±2.2 (N=30)	86.2± 2.1 (N=69)
3	19 July-Low	49.9±1.9 (N=25)	54.4±1.8 (N=28)	58.9±1.4 (N=55)	63.1±1.6 (N=43)	68.0±2.7 (N=23)	90.0± 1.9 (N=51)
			30 Aug	20-22 Sept	20-22 Oct	9-13 March	11 April-9 June
4	30 Aug-High		57.2±1.3 (N=44)	57.7±1.2 (N=55)	59.2±1.6 (N=48)	65.0±1.9 (N=35)	85.6± 1.5 (N=68)
5	30 Aug-Medium		57.2±1.3 (N=44)	59.2±1.2 (N=57)	62.4±1.3 (N=52)	69.4±1.9 (N=34)	89.0± 2.0 (N=47)
6	30 Aug-Low		57.2±1.3 (N=44)	59.2±2.0 (N=15)	60.4±1.7 (N=38)	76.8±4.8 (N=12)	89.5± 2.5 (N=52)
				8 Oct	29-30 Oct	17-19 March	12 April-5 June
7	8 Oct-High			85.6±2.0 (N=50)	85.3±2.2 (N=43)	89.9±2.0 (N=51)	111.3±1.9 (N=127)
8	8 Oct-Medium			85.6±2.0 (N=50)	85.7±1.8 (N=60)	93.4±2.1 (N=30)	118.7± 3.2 (N=61)
9	8 Oct-Low			85.6±2.0 (N=50)	85.7±1.9 (N=39)	No Data	118.7±15.3 (N=4)

Table 29. Seasonal variations in condition (K) for coho salmon in Banon Creek, July 1980 to July 1981.

Section No.	Stocking Density	Sampling Periods					
		1980				1981	
		21 July	14-16 Aug	12-17 Sept	15-16 Oct	13-14 April	2-3 July
1	High	1.127	1.344	1.223	1.100	1.245	1.092
2	Medium	1.127	1.283	1.282	1.114	1.235	1.108
3	Low	1.127	1.249	1.192	1.154	1.309	1.095
			30 Aug	20-22 Sept	20-22 Oct	9-13 March	26-29 June
4	High	-	0.962	1.198	1.123	1.324	1.116
5	Medium	-	0.962	1.120	1.166	1.297	1.083
6	Low	-	0.962	1.211	1.165	1.219	1.082
				8 Sept	27-28 Oct	23-25 March	6 July
7	High	-	-	1.244	1.185	1.237	1.034
8	Medium	-	-	1.244	1.168	1.219	1.035
9	Low	-	-	1.244	1.148	1.264	1.018
		21 July	23 Aug	25 Sept	21 Oct	23 March	2 July
Mean		1.127	1.127	1.218	1.147	1.261	1.074

Table 30. Seasonal variations in condition (K) for coho salmon in Bush Creek, July 1980 to July 1981.

Section No.	Stocking Density	Sampling Periods					
		1980				1981	
		19 July	10-14 Aug	8-9 Sept	11-14 Oct	5-8 March	24-25 June
1	High	1.127	1.062	1.145	1.258	1.334	1.104
2	Medium	1.127	1.031	1.076	1.193	1.344	1.093
3	Low	1.127	1.304	1.126	0.915	1.336	1.097
			30 Aug	20-22 Sept	20-22 Oct	9-13 March	26-29 June
4	High	-	0.962	1.093	1.157	1.457	1.100
5	Medium	-	0.962	1.109	1.111	1.286	1.092
6	Low	-	0.962	1.205	1.135	1.258	1.074
				8 Oct	29-30 Oct	17-19 March	1 July
7	High	-	-	1.244	1.096	1.308	1.066
8	Medium	-	-	1.244	1.112	1.227	1.184
9	Low	-	-	1.244	1.112	No Data	1.088
		19 July	21 Aug	23 Sept	21 Oct	11 March	28 June
Mean		1.127	1.047	1.165	1.121	1.317	1.100

Table 31. Seasonal variations in mean weight (g,±2SE,N) for the 1980 cutthroat trout year class in Banon Creek, 23 July 1980 to 6 July 1981.

Section No.	Sampling Periods					
	1980				1981	
		14-16 Aug	12-17 Sept	15-16 Oct	13-14 April	2-3 July
1	-	0.5±0.2(21)	1.2±0.1(44)	1.6±0.2(34)	1.9±0.5(10)	6.2±1.6(16)
2	-	0.6±0.1(40)	1.2±0.1(48)	1.2±0.2(30)	1.8±0.5(9)	7.6±1.6(12)
3	-	0.5±0.1(20)	1.6±0.2(58)	1.7±0.2(37)	2.3±0.3(20)	7.4±0.6(25)
			20-22 Sept	20-22 Oct	9-13 March	26-29 June
4	-	-	1.7±0.2(49)	1.7±0.3(33)	2.2±0.3(20)	7.5±0.9(17)
5	-	-	1.5±0.2(44)	1.9±0.2(38)	2.0±0.4(18)	7.8±1.0(14)
6	-	-	2.3±0.2(54)	2.1±0.2(49)	1.9±0.3(13)	7.6±1.1(15)
			2 Oct	27-28 Oct	23-25 March	6 July
7	-	-	1.7±0.2(20)	1.9±0.2(42)	1.8±0.6(9)	6.5±1.0(12)
8	-	-	2.2±0.4(10)	2.5±0.2(41)	2.5±0.3(22)	8.1±0.9(16)
9	-	-	2.0±0.4(11)	2.3±0.2(51)	2.5±0.4(4)	7.6±0.6(41)
	23-25 July	11 Aug	4 Sept	25 Sept	14 April	6 July
10	0.23(12)	0.5±0.1(60)	1.7±0.2(26)	2.3±0.2(33)	2.1±0.3(14)	7.5±0.5(44)

Table 32. Seasonal variations in mean fork length (mm,±2SE,N) for the 1980 cutthroat trout year class in Banon Creek 23 July 1980 to 6 July 1981.

Section No.	Sampling Periods 1980				1981	
		14-16 Aug	12-17 Sept	15-16 Oct	13-14 April	2-3 July
1	-	38.7±2.8(21)	47.7±1.4(44)	55.1±2.3(34)	57.3±4.3(10)	78.3±4.4(15)
2	-	39.9±1.8(40)	47.8±1.5(48)	49.9±1.9(30)	57.2±4.5(9)	82.6±7.3(10)
3	-	37.3±1.6(20)	53.2±1.3(58)	55.8±2.0(37)	59.2±2.2(20)	84.0±3.0(25)
			20-22 Sept	20-22 Oct	9-13 April	26-29 June
4	-	-	54.5±1.9(49)	55.5±2.3(33)	59.1±2.8(20)	85.4±4.2(18)
5	-	-	52.2±1.9(44)	57.1±2.3(38)	58.1±2.5(18)	87.3±4.4(15)
6	-	-	57.8±2.7(54)	59.6±1.7(49)	57.2±2.3(13)	88.3±4.1(16)
			2 Oct	27-28 Oct	23-25 March	6 July
7	-	-	55.4±2.4(20)	56.6±1.7(42)	57.9±3.5(9)	83.1±3.7(12)
8	-	-	58.2±2.6(10)	60.1±1.7(41)	58.0±5.5(22)	87.9±3.6(16)
9	-	-	58.6±3.4(11)	58.8±1.7(51)	60.5±2.4(4)	86.7±2.3(42)
	23-25 July	11 Aug	4 Sept	25 Sept	14 April	6 July
10	28.4±2.5(10)	39.0±1.4(60)	55.0±1.7(26)	59.2±1.6(33)	59.6±2.9(14)	84.6±2.4(42)

Table 33. Seasonal variations in mean weight (g,±2SE,N) for the 1980 cutthroat trout year class in Bush Creek, 10 August 1980 to 1 July 1981.

Section No.	Sampling Periods				
	1980			1981	
	10-14 August	8-9 Sept	11-14 Oct	5-8 March	24-25 June
1	1.3±0.2(31)	1.9±0.2(48)	2.6±0.3(36)	3.3±0.5(13)	8.8±0.7(28)
2	1.1±0.2(34)	2.0±0.2(45)	2.4±0.2(39)	3.8±0.7(13)	8.7±0.6(37)
3	1.3±0.2(32)	2.1±0.2(33)	2.6±0.2(29)	3.3±0.7(11)	8.6±0.5(35)
		20-22 Sept	20-22 Oct	9-13 March	26-29 June
4	-	2.3±0.2(49)	2.3±0.2(39)	2.8±0.4(16)	8.8±0.6(34)
5	-	2.7±0.3(34)	2.7±0.2(27)	3.9±0.9(9)	9.1±0.4(22)
6	-	2.4±0.2(41)	2.7±0.2(40)	4.1±0.5(21)	9.3±0.6(32)
		2 Oct	29-30 Oct	17-19 March	1 July
7	-	2.3±0.2(37)	2.5±0.2(54)	3.5±0.3(44)	8.9±0.6(39)
8	-	2.7±0.2(35)	2.7±0.2(60)	5.1±0.6(27)	8.9±0.4(59)
9	-	2.7±0.2(40)	2.7±0.2(59)	3.9±0.5(35)	9.6±0.6(41)
	22 Aug	22 Sept	21 Oct	20 March	1 July
10	1.4±0.1(30)	1.9±0.2(22)	1.8±0.2(19)	4.3±0.7(23)	9.7±0.7(30)

Table 34. Seasonal variation in mean fork length (mm,±2SE,N) for the 1980 cutthroat trout year class in Bush Creek, 10 August 1980 to 1 July 1981.

Section No.	Sampling Periods				
	1980			1981	
	10-14 August	8-9 Sept	11-14 Oct	5-8 March	24-25 June
1	50.5±2.4(31)	57.6±1.0(48)	61.7±2.1(36)	64.5±3.8(13)	92.9±2.9(28)
2	47.4±2.0(34)	57.8±1.6(45)	60.1±1.7(39)	62.6±3.6(13)	93.1±2.3(39)
3	48.8±2.0(32)	59.6±1.1(33)	62.9±2.0(29)	64.0±5.1(11)	92.1±2.3(36)
		20-22 Sept	20-22 Oct	9-13 March	26-29 June
4	-	59.1±1.5(49)	60.5±1.9(39)	61.1±2.5(16)	90.5±2.4(34)
5	-	61.9±1.9(34)	63.7±2.0(27)	65.5±3.0(9)	92.7±1.7(21)
6	-	60.5±1.6(41)	64.2±1.5(40)	69.6±2.8(21)	93.8±2.5(33)
		2 Oct	29-30 Oct	17-19 March	1 July
7	-	58.0±3.5(37)	61.5±1.2(54)	65.5±2.3(44)	91.5±2.4(39)
8	-	62.1±1.8(35)	64.1±1.5(60)	73.4±2.9(27)	92.0±1.8(61)
9	-	62.9±1.5(40)	63.8±1.4(59)	67.3±2.5(35)	96.1±2.3(44)
	22 August	22 Sept	21 Oct	20 March	1 July
10	49.7±1.8(30)	55.9±2.1(22)	57.6±2.6(19)	69.9±1.3(23)	93.9±2.3(31)

Table 35. Variations in the overall mean weight of cutthroat trout young-of-the-year (the 1980 year class) in Sections stocked at different times and densities with coho salmon.

Group	Mean wt(g)-Banon Creek 15-28 Oct 1980	Mean wt(g)-Banon Creek 26 June - 6 July 1981	Mean wt(g)-Bush Creek 11-30 Oct 1980	Mean wt(g)-Bush Creek 24 June - 1 July 1981
Stocking Time				
19-21 July	2.0	7.1	2.5	8.7
30 August	2.0	7.6	2.6	9.1
8 October	2.3	7.5	2.6	9.1
Stocking Density				
High	1.7	6.8	2.5	8.8
Medium	1.9	7.9	2.6	8.9
Low	2.1	7.5	2.7	9.2

Table 36. Seasonal variations in condition (K) for the 1980 cutthroat trout year class in Banon Creek, July 1980 to July 1981.

Section No.	Sampling Period					
	1980				1981	
		14-16 Aug	12-17 Sept	15-16 Oct	13-14 April	2-3 July
1		0.863	1.106	0.956	1.010	1.292
2		0.945	1.099	0.966	0.962	1.349
3		0.963	1.063	0.978	1.109	1.249
			20-22 Sept	20-22 Oct	9-13 March	26-29 June
4		-	1.050	0.994	1.066	1.204
5		-	1.055	1.021	1.020	1.172
6		-	1.191	0.992	1.015	1.104
			2 Oct	27-28 Oct	23-25 March	6 July
7		-	1.000	1.048	0.927	1.134
8		-	1.116	1.152	1.281	1.193
9		-	0.994	1.131	1.129	1.167
	23-25 July	5 Sept	25 Sept	22 Oct	14 April	6 July
10	1.004	0.843	1.022	1.109	0.992	1.239
Mean	24 July	20 Aug	23 Sept	20 Oct	2 April	4 July
	1.004	0.903	1.070	1.034	1.051	1.210

Table 37. Seasonal variations in condition (K) for the 1980 cutthroat trout year class in Bush Creek, August 1980 to July 1981.

Section No.	Sampling Periods				
	1980			1981	
	10-14 Aug	8-9 Sept	11-14 Oct	5-8 March	24-25 June
1	1.009	0.994	1.107	1.230	1.098
2	1.033	1.035	1.106	1.549	1.078
3	1.119	0.992	1.045	1.259	1.101
		20-22 Sept	20-22 Oct	9-13 March	26-29 June
4	-	1.114	1.039	1.228	1.187
5	-	1.138	1.045	1.382	1.142
6	-	1.084	1.020	1.216	1.127
		2 Oct	29-30 Oct	17-19 March	1 July
7	-	1.179	1.075	1.246	1.162
8	-	1.127	1.025	1.290	1.143
9	-	1.085	0.040	1.279	1.082
	22 Aug	22 Sept	21 Oct	20 March	1 July
10	1.140	1.087	0.942	1.259	1.172
Mean	15 Aug	20 Sept	21 Oct	13 March	28 June
	1.076	1.083	1.045	1.294	1.129

Table 38. Seasonal variations in mean weight (g,±2SD,N) for the 1976 to 1979 cutthroat trout year classes in Banon Creek, July 1980 to July 1981.

Section No.	Year Class	Sampling Dates					
		1980				1981	
		10-13 July	14-16 August	12-17 Sept	15-16 Oct	13-14 April**	2-3 July
1	1979	6.9	8.2± 3.7(11)	9.0± 4.1(20)	8.0± 3.2(15)	9.6± 2.0(7)	19.5± 4.1(9)
	1978	19.1	17.5± 7.7(9)	17.7±10.2(8)	15.7± 4.2(6)	21.2±13.4(9)	27.4± (1)
	1977	50.4	33.9±12.0(2)	41.7 (1)		44.4±20.8(5)	
2	1979	10.0	9.0± 4.5(12)	8.7± 4.0(22)	9.4± 5.0(11)		18.6± 5.5(9)
	1978	18.3	20.2±12.2(9)	17.1± 9.0(15)	14.9± 4.6(8)		29.5± 9.0(3)
	1977	39.5	45.0± 7.6(4)	47.1±27.8(3)	28.9± 1.8(2)		
3	1979	8.1	9.7± 4.2(20)	9.4± 4.0(23)	9.2± 1.6(16)		17.4± 3.2(6)
	1978	17.5	17.7± 8.0(10)	16.6± 8.6(11)	16.2± 7.1(4)		25.6 (1)
	1977	35.1	32.7± 8.7(4)	36.3±15.8(3)	29.2± 6.8(3)		
			23 August***	20-22 Sept	20-22Oct	9-13 March	26-29 June
4	1979		8.7	9.1± 3.4(33)	8.0± 2.8(21)	9.8± 3.0(18)	18.6± 8.5(24)
	1978		14.4	19.1± 7.2(20)	19.3±11.4(19)	17.3±10.6(15)	33.5±10.0(4)
	1977		33.7	29.6± 7.3(3)	29.1±12.8(2)	34.5±13.2(3)	86.2 (1)
	1976				81.8 (1)		
5	1979			9.6± 3.2(13)	8.3± 3.4(12)		18.2± 7.8(15)
	1978			20.1± 7.6(18)	18.7± 5.2(12)		41.3±22.2(13)
	1977			44.5±27.6(12)	37.4±23.8(10)		
	1976				72.4 (1)		

Continued

Table 38. Continued

Section No.	Year Class	Sampling Dates					
		1980				1981	
			23 August***	20-22 Sept	20-22 Oct	9-13 March	26-29 June
6	1979			9.4± 2.4(21)	9.0± 3.4(29)		16.0± 7.1(5)
	1978			18.8±11.6(14)	14.6± 6.0(18)		33.1± 9.6(3)
	1977			40.1±33.2(11)	40.5±10.5(4)		
				2 Oct	27-28 Oct	23-25 March	6 July
7	1979			9.0± 3.6(15)	8.3± 3.2(15)	10.2± 5.0(21)	21.5± 8.4(11)
	1978			17.4± 9.6(16)	17.5± 9.0(15)	18.8±12.4(21)	36.9±14.5(6)
	1977			31.0± 5.8(3)	30.1±13.2(3)	40.6±15.0(5)	
8	1979			9.3± 4.1(13)	10.0± 3.8(27)		17.7±11.6(4)
	1978			19.7±13.2(12)	16.7± 7.7(21)		44.7±11.6(2)
	1977			37.3±14.2(4)	36.1±23.4(11)		
9	1979			9.6± 3.2(12)	9.5± 3.4(22)		17.2± 7.8(18)
	1978			18.6±10.4(8)	17.7± 5.8(17)		39.0 (1)
	1977			34.1 (1)	38.4±24.0(5)		
		23-25 July	11 August	4 Sept	25 Sept		
10	1979	7.3± 3.2(39)	8.7± 2.8(28)	9.0± 4.2(24)	8.5± 2.8(16)		
	1978	15.8± 9.4(30)	16.8± 9.6(7)	19.5± 6.1(17)	17.7± 7.4(12)		
	1977	38.0±21.6(8)	40.4±26.2(8)	42.4±27.4(7)	37.8± 9.0(4)		

Continued

Table 38. Concluded

Section No.	Year Class	Sampling Dates		
		1980	1981	
		22 Oct	14 April	6 July
10	1979	8.8± 3.7(21)	9.9± 3.0(10)	16.0± 6.4(21)
	1978	18.1± 9.6(14)	17.6± 8.2(7)	45.1±20.3(5)
	1977	40.1±38.6(5)	39.3±16.8(4)	

*based on length-weight relationships
**composite samples from three sections
***assumed to be similar to control Section (10)

Table 39. Seasonal variations in mean weight (g,±2SD,N) for the 1976 to 1979 cutthroat trout year classes in Bush Creek, June 1980 to July 1981.

Section No.	Year Class	Sampling Dates					
		1980				1981	
		25-29 June*	10-14 August	8-9 Sept	11-14 Oct	5-8 March**	24-25 June
1	1979	8.6	7.5± 1.6(7)	8.8± 4.8(13)	8.2± 2.1(13)	11.7± 8.0(21)	19.4± 7.2(6)
	1978	15.7	17.7±11.2(15)	15.5± 9.6(8)	18.6±10.6(10)	21.1± 9.8(8)	36.0±18.6(7)
	1977	54.2	38.1±42.0(4)	32.4± 7.8(3)	33.0±14.8(3)	41.4±18.2(5)	36.0±18.6(7)
2	1979	8.7	9.1± 2.8(24)	8.9± 3.0(17)	8.7± 2.2(9)		15.1± 4.8(8)
	1978	16.8	15.9± 8.5(20)	14.2± 5.4(7)	16.7±13.8(15)		35.0±14.4(9)
	1977	35.4	29.2 (1)	45.1±15.6(3)	41.9 (1)		
3	1979	8.3	10.1± 2.8(20)	8.9± 3.4(21)	9.2± 2.7(19)		19.1± 9.6(21)
	1978	17.3	18.3± 8.8(17)	17.3± 9.0(15)	18.7± 9.5(14)		40.0±26.5(8)
	1977	25.3	39.4±17.2(6)	36.7±13.8(6)	38.9±21.0(7)		
			23 August***	20-22 Sept	20-22 Oct	9-13 March	26-29 June
4	1979		8.7	9.1± 3.4(33)	8.0± 2.8(21)	11.0± 6.8(28)	18.6± 8.5(24)
	1978		14.4	19.1± 7.2(20)	19.3±11.4(19)	23.5± 8.8(21)	33.5±10.0(4)
	1977		33.7	29.6± 7.3(3)	29.1±12.8(2)	49.2±19.6(7)	86.2 (1)
	1976				81.8 (1)		
5	1979			9.6± 3.2(13)	8.3± 3.4(12)		18.2± 1.8(15)
	1978			20.1± 7.6(18)	18.7± 5.2(12)		41.3±11.2(13)
	1977			44.5±27.6(12)	37.4±23.8(10)		
					72.4 (1)		

Continued

Table 39. Continued

Section No.	Year Class	Sampling Dates				
		1980			1981	
		23 August***	20-22 Sept	20-22 Oct	9-13 March	26-29 June
6	1979		9.1± 3.6(12)	9.2± 2.6(10)		19.6±11.4(15)
	1978		17.7± 6.4(19)	17.8± 7.6(20)		38.7±26.6(4)
	1977		34.4± 6.9(6)	39.2±24.6(8)		75.6 (1)
	1976			89.2 (1)		
			2 Oct	29-30 Oct	17-19 March	1 July
7	1979		9.0± 3.2(14)	8.4± 3.8(23)	11.6± 5.4(29)	18.8± 7.1(15)
	1978		19.7± 9.2(16)	17.5± 7.9(25)	22.6±11.8(25)	40.0±23.9(12)
	1977		43.5±29.2(10)	35.3±22.6(16)	51.2±19.6(13)	
8	1979		9.2± 2.8(9)	9.1± 3.6(21)		19.2±10.0(24)
	1978		17.1±10.2(17)	15.5± 8.0(14)		38.9±29.0(12)
	1977		40.8±21.4(6)	45.2±21.8(9)		111.8 (1)
	1976			68.4 (1)		
9	1979		9.9± 2.8(11)	9.3± 2.5(19)		17.6± 7.4(16)
	1978		15.6± 9.2(12)	14.8± 7.4(20)		40.2±22.0(7)
	1977		38.1±25.9(3)	43.9±26.2(10)		
	1976		74.2 (1)	72.6 (1)		

Continued

Table 39. Concluded

Section No.	Year Class	Sampling Dates					
		1980				1981	
		1 July	8 August	22 August	22 Sept		
10	1979	8.4± 2.8( )	9.3± 3.0(20)	8.7± 1.4(12)	9.1± 3.5(12)		
	1978	23.5±16.1( )	16.0± 8.0(5)	14.4± 6.4(8)	14.3± 4.8(8)		
	1977	34.4±26.6( )	41.8±19.0(4)	33.7±13.8(3)	39.8±27.4(3)		
	1976	70.2±14.0(2)	82.0 (1)				
					21 Oct	20 March	1 July
10	1979				9.1± 1.8(11)	11.3± 4.4(7)	17.1± 7.3(11)
	1978				14.6± 6.2(6)	22.3±11.6(8)	33.1±12.2(4)
	1977				40.9±31.2(3)	39.9±10.0(3)	

*based on length-weight relationships
**composite samples from three sections
***assumed to be similar to control Section No. 10

Table 40. Variations in the mean weight of yearling cutthroat trout (the 1979 year class) in Sections stocked at different times and densities with coho salmon.

Group	Mean Wt(g)-Banon Creek		Mean Wt(g)-Bush Creek	
	15-28 Oct 1980	26 June - 6 July 1981	11-30 Oct 1980	24 June - 1 July 1981
Stocking Time				
19-21 July	8.8	18.6	8.8	18.2
30 August	8.5	18.2	8.4	18.8
8 October	9.4	19.0	8.9	18.6
Stocking Density				
High	8.1	19.5	8.2	18.8
Medium	9.5	18.3	8.7	18.2
Low	9.2	17.4	9.4	18.8
Control	8.8	16.0	9.1	17.1

Table 41. Variations in the overall mean weight of two year old cutthroat trout (the 1978 year class) in Sections stocked at different times and densities with coho salmon.

	Mean Wt(g)-Banon Creek		Mean Wt(g)-Bush Creek	
Group	15-28 Oct 1980	26 June - 6 July 1981	11-30 Oct 1980	24 June - 1 July 1981
Stocking Time				
19-21 July	15.5	28.3	17.9	37.0
30 August	17.4	38.5	18.6	39.3
8 October	17.2	38.9	16.1	39.6
Stocking Density				
High	18.1	34.8	19.3	37.7
Medium	16.9	39.7	17.4	38.8
Low	16.1	32.8	17.4	39.8
Control	18.1	45.1	14.6	33.1

Table 42. Coho salmon and cutthroat trout production in Banon Creek.

Section No.	Cutthroat Trout Production (g/m^2)					Coho Salmon Production (g/m^2)				Grand Total
	Fry	Older Fish			Total					
	8 Oct-10 June	21 July-10 June	30 Aug-10 June	8 Oct-10 June	8 Oct-10 June	21 July-10 June	30 Aug-10 June	8 Oct-10 June	Total	8 Oct-10 June
1	0.13	0.14	0.15	0.18	0.31	1.89	1.02	0.98	1.89	1.29
2	0.13	0.13	0.12	0.22	0.35	1.09	0.58	0.54	1.09	0.89
3	0.24	0.23	0.21	0.25	0.49	0.85	0.54	0.47	0.85	0.96
4	0.28		0.26	0.34	0.56		1.56	1.02	1.56	1.58
5	0.34		0.40	0.60	0.90		1.67	1.24	1.67	2.14
6	0.15		0.15	0.19	0.34		0.54	0.36	0.54	0.70
7	0.24			0.81	1.05			0.26	0.26	1.31
8	0.26			0.60	0.86			0.13	0.13	0.99
9	0.28			0.44	0.72			0.20	0.20	0.92
Average Production	0.23	0.17	0.21	0.40	0.62	1.28	0.99	0.58	0.91	1.20
10 (Control)	0.20	0.54	0.31	0.38	0.58					

Table 43. Coho salmon and cutthroat trout production in Bush Creek.

Section No.	Cutthroat Trout Production(g/m²)					Coho Salmon Production(g/m²)				Grand Total 8 Oct-10 June
	Fry	Older Fish			Total					
	8 Oct-10 June	20 July-10 June	30 Aug-10 June	8 Oct-10 June	8 Oct-10 June	21 July-10 June	30 Aug-10 June	8 Oct-10 June	Total	
1	0.50	0.77	0.88	0.86	1.36	1.91	1.51	1.12	1.91	2.48
2	0.67	0.42	0.36	0.34	1.01	1.35	1.03	0.76	1.35	1.77
3	0.53	1.57	1.51	1.47	2.00	0.92	0.72	0.59	0.92	2.59
4	0.55		1.98	1.76	2.31		0.92	0.66	0.92	2.97
5	0.29		1.62	1.38	1.67		1.07	0.78	1.07	2.45
6	0.34		1.21	1.08	1.54		0.34	0.25	0.34	1.79
7	1.02			2.10	3.12			1.52	1.52	4.64
8	1.17			2.19	3.36			1.54	1.54	4.90
9	1.13			1.08	2.21			-	-	-
Average Production	0.67	0.92	1.26	1.36	2.06	1.39	0.93	0.90	1.20	2.95
10 (Control)	1.25	0.63	0.80	0.74	1.99					

Table 44. Summary of mean biomass ($\bar{B}$), production (P), P/$\bar{B}$ ratios, and % yield by coho stocked at three different times and densities in Banon and Bush Creek.

Experimental Group	Mean Biomass (g/m²)		Production (g/m²)		P/$\bar{B}$		% Yield
	Overall	8 Oct-10 June	Overall	8 Oct-10 June	Overall	8 Oct-10 June	
Banon Creek							
21 July Stocking	0.76	0.57	1.28	0.66	1.68	1.09	47.0
30 Aug Stocking	0.86	0.77	1.26	0.87	1.50	1.15	62.6
8 Oct Stocking	1.59	1.59	0.20	0.20	0.17	0.17	44.9
High Density Stocking	1.63	1.47	1.24	0.75	1.07	0.81	37.7
Medium Density Stocking	1.10	1.00	0.96	0.64	1.05	0.75	45.9
Low Density Stocking	0.47	0.47	0.53	0.34	1.23	0.85	70.9
Bush Creek							
19 July Stocking	0.93	0.68	1.39	0.82	1.54	1.00	54.6
30 Aug Stocking	0.59	0.47	0.77	0.56	1.32	1.20	48.9
8 Oct Stocking*	2.05	2.05	1.53	1.53	0.75	0.75	64.5
High Density Stocking	1.42	1.28	1.45	1.10	1.13	0.97	46.6
Medium Density Stocking	1.21	1.12	1.32	1.03	1.19	0.96	41.8
Low Density Stocking*	0.39	0.38	0.63	0.42	1.57	1.13	86.9

*8 October low density stocking not included.

Table 45. Summary of mean biomass ($\bar{B}$), production (P) and the ratio of these two parameters ($P/\bar{B}$) for cutthroat trout in Sections stocked with coho at three different times and densities in Banon and Bush Creek. The product of mean biomass and the $P/\bar{B}$ ratio in the control Section is used to estimate production in the absence of coho.

Experimental Group	Mean Biomass B (g/m²)	Mean Observed Production P (g/m²)	Mean $P/\bar{B}$	Control $P/\bar{B}$	Expected Production (gm/m²)	% Difference from Observed Production
Banon Creek						
21 July Stocking	0.54	0.33	0.61	0.71	0.38	13.0
30 Aug Stocking	1.06	0.53	0.48	0.53	0.56	5.3
8 Oct Stocking	1.31	0.88	0.68	0.71	0.93	5.4
High Density Stocking	1.00	0.62	0.62	0.65	0.65	4.6
Medium Density Stocking	1.13	0.62	0.53	0.65	0.73	15.0
Low Density Stocking	0.78	0.50	0.63	0.65	0.51	2.0
Bush Creek						
19 July Stocking	1.58	1.49	0.95	1.27	2.01	25.9
30 Aug Stocking	2.47	2.00	0.81	1.39	3.43	41.7
8 Oct Stocking	3.95	2.30	0.76	1.26	4.98	41.8
High Density Stocking	2.94	2.31	0.79	1.31	3.85	40.0
Medium Density Stocking	2.70	2.12	0.85	1.31	3.54	40.1
Low Density Stocking	2.23	1.95	0.88	1.31	2.92	3.33

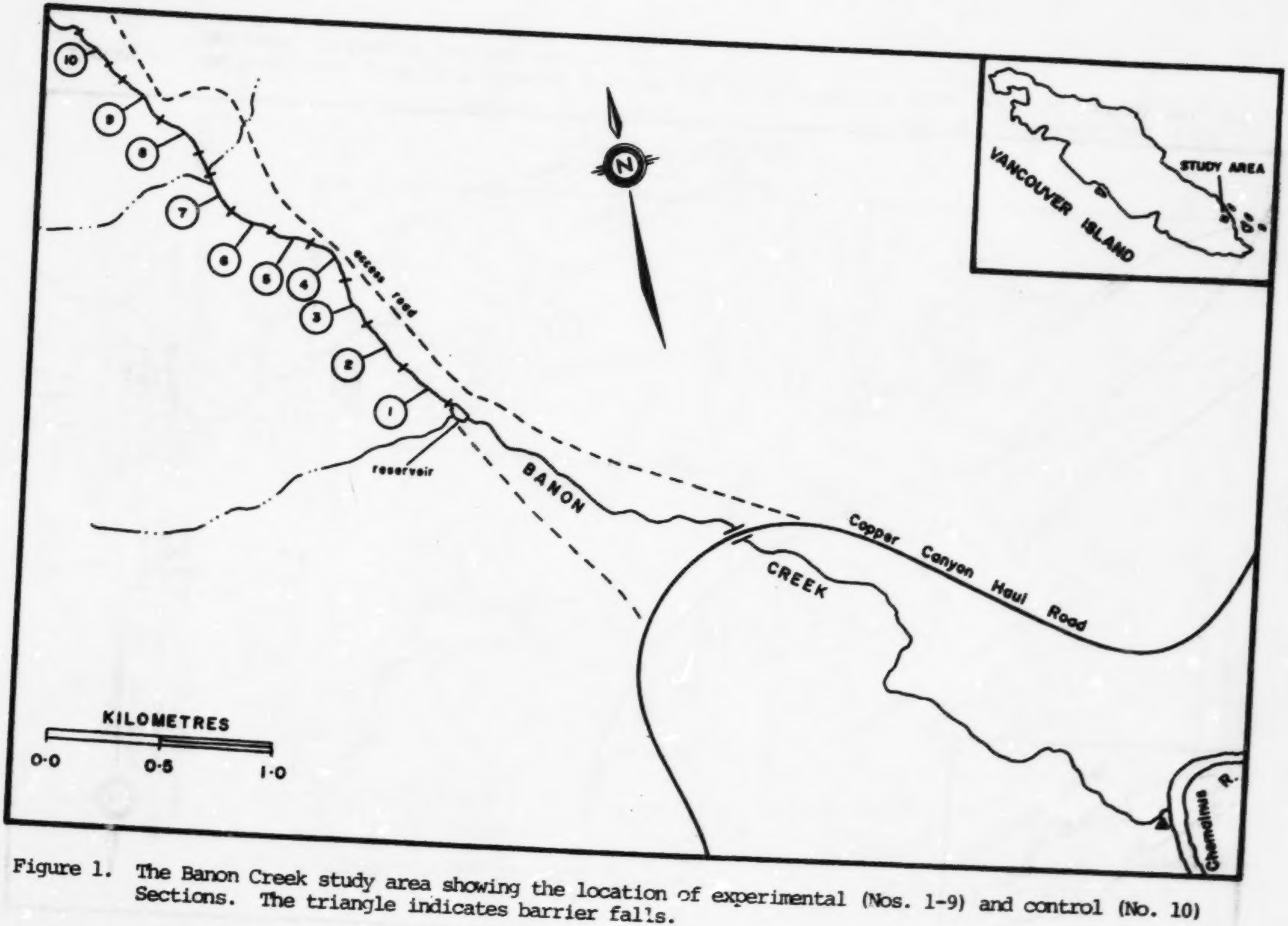
10
9
8
7
6
5
4
3
2
1
access road
reservoir
BANON
CREEK
Copper Canyon Haul Road
Chemainus R.
N
VANCOUVER ISLAND
STUDY AREA
KILOMETRES
0·0
0·5
1·0

Figure 1. The Banon Creek study area showing the location of experimental (Nos. 1-9) and control (No. 10) Sections. The triangle indicates barrier falls.

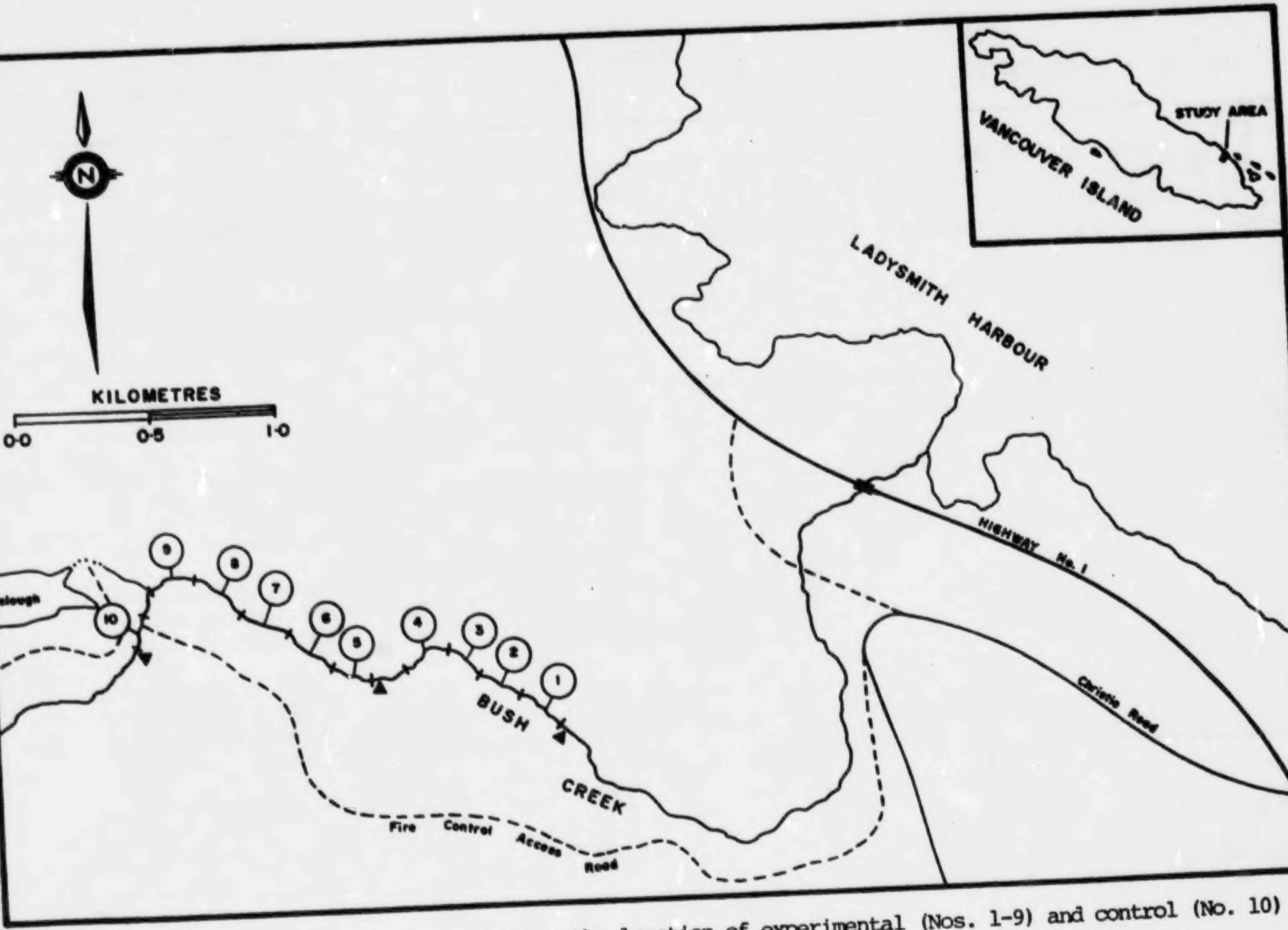
STUDY AREA
VANCOUVER ISLAND
LADYSMITH HARBOUR
HIGHWAY No. 1
Christie Road
N
KILOMETRES
0·0
0·5
1·0
slough
10
9
8
7
6
5
4
3
2
1
BUSH CREEK
Fire Control Access Road

Figure 2. The Bush Creek study area showing the location of experimental (Nos. 1-9) and control (No. 10) Sections. Triangles indicate barrier falls.

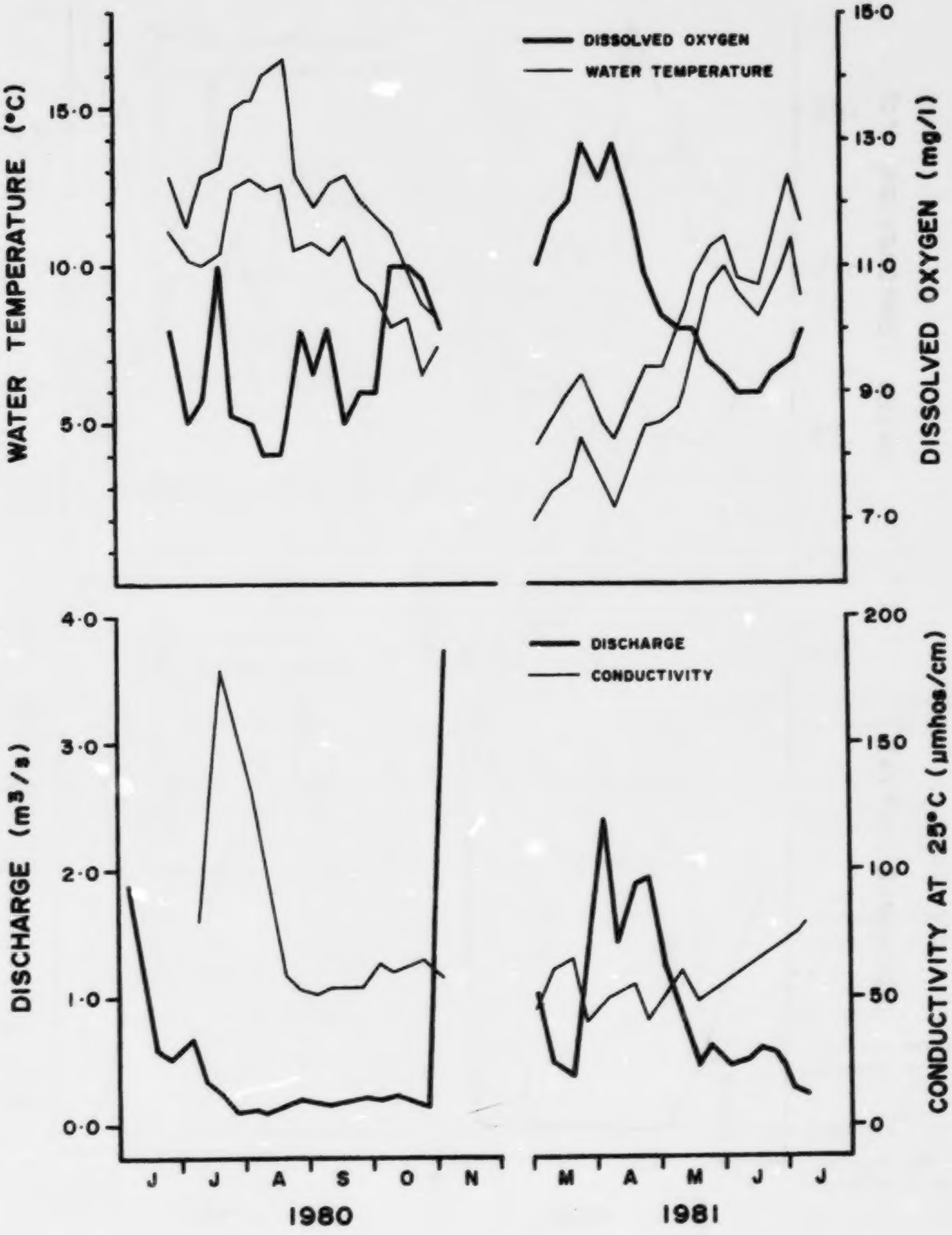

Figure 3. Seasonal variations in mean weekly maximum/minimum water temperature (C), dissolved oxygen concentration (mg/L), conductivity (μmhos/cm), and discharge (m³/s) in Banon Creek, 11 June to 6 November 1980 and 9 March to 6 July 1981.

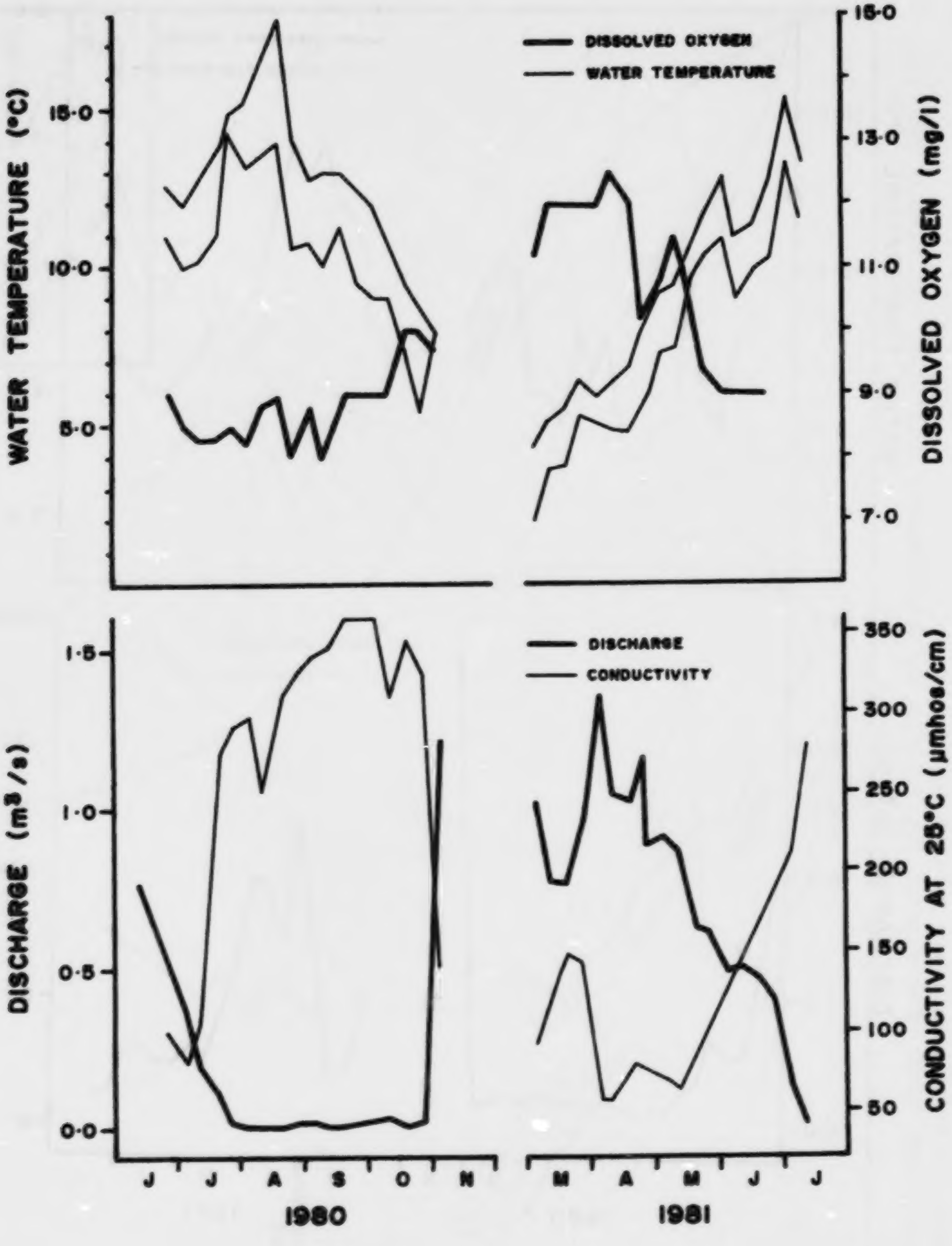

Figure 4. Seasonal variations in mean weekly maximum/minimum water (C), dissolved oxygen concentration (mg/L), conductivity (umhos/cm) and discharge (m³/s) in Bush Creek, 11 June to 6 November 1980 and 9 March to 6 July 1981.

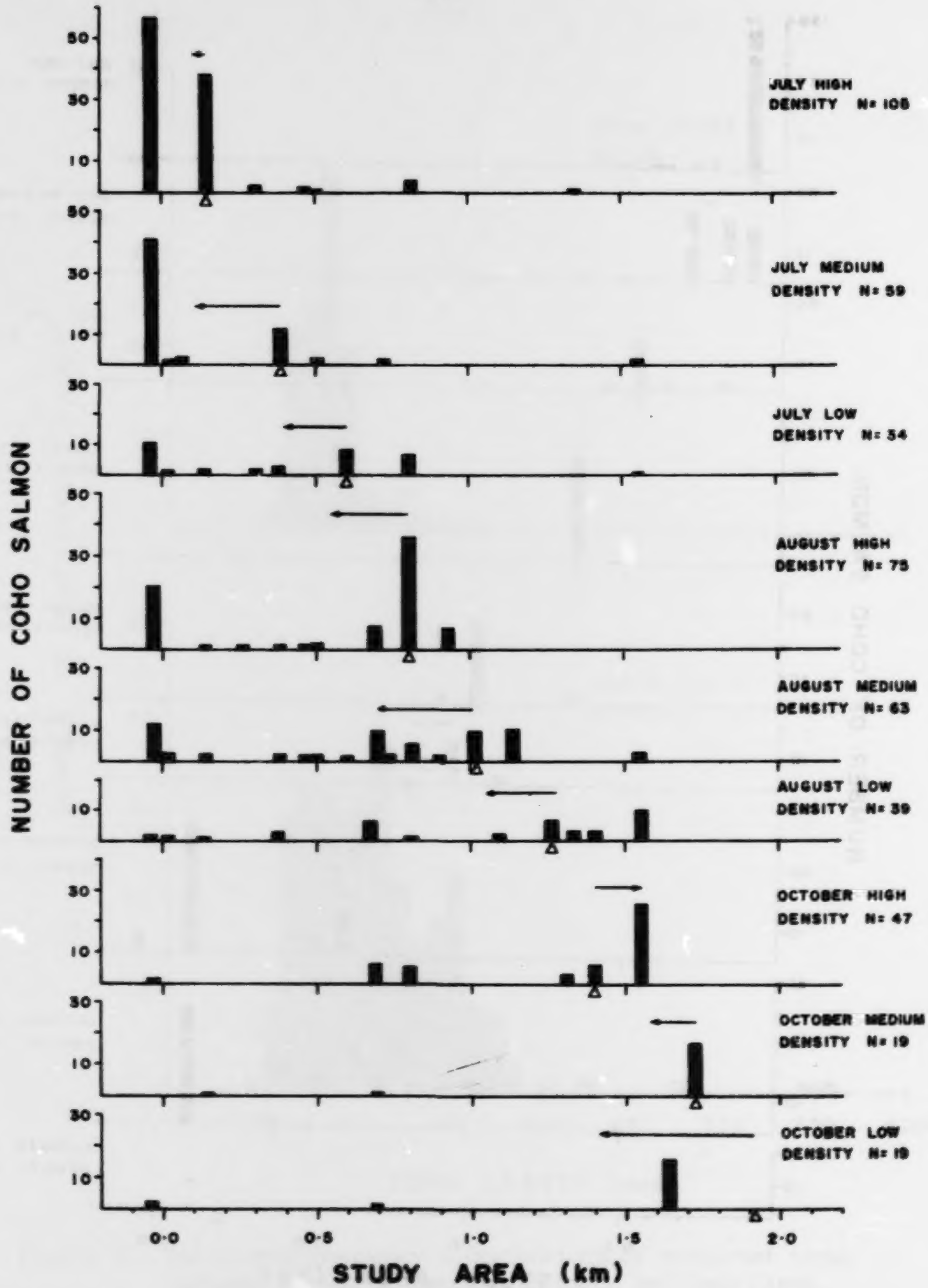

Figure 5. Distribution of coho salmon in the Banon Creek study area, 23 March to 14 April 1981 for the stream reaches from 0.0 to 2.0 km, and 14 May through 22 May for the reservoir (below 0.0 km). Arrows originate at the center of each Section (△) and indicate the direction and average net movement of fish stocked in each Section.

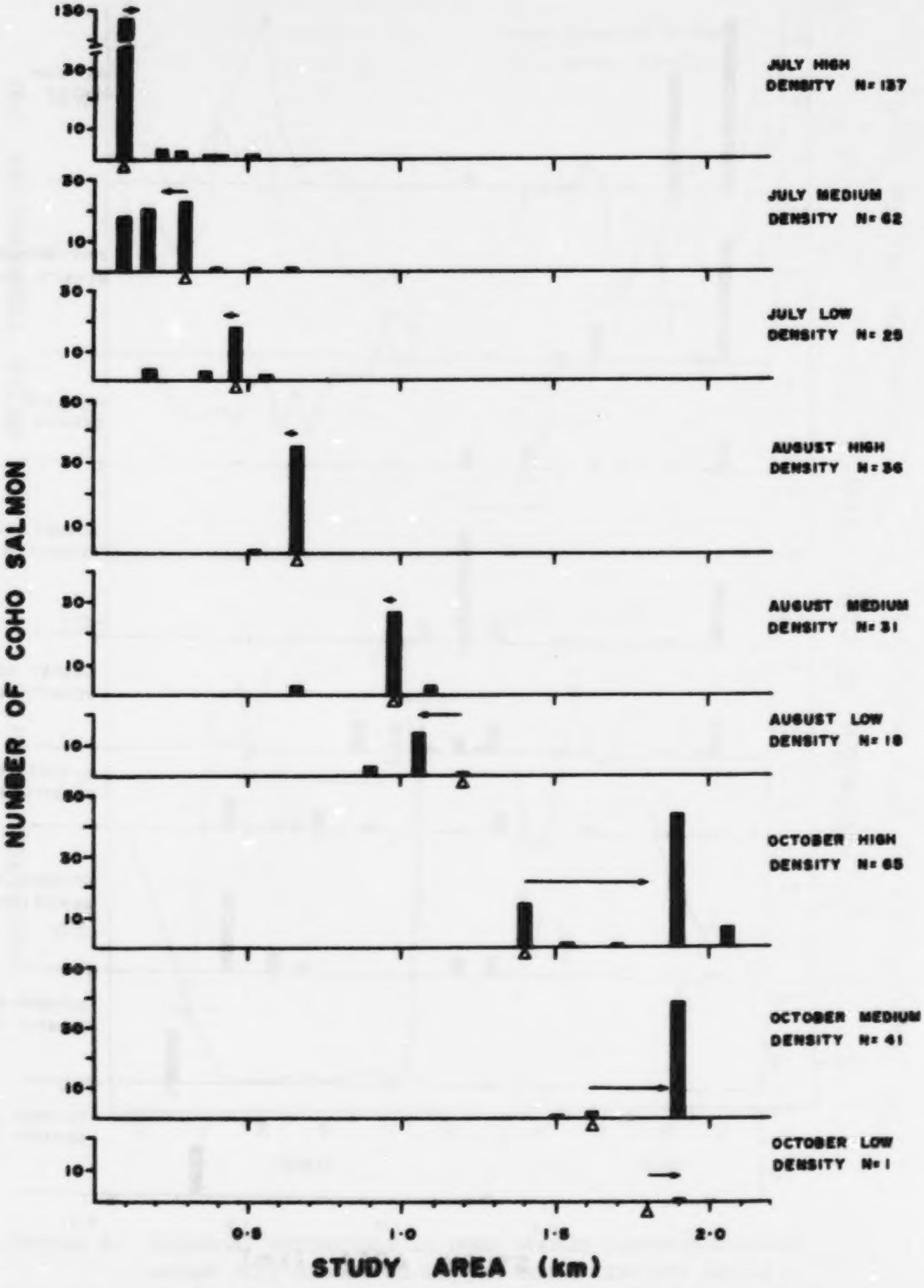

Figure 6. Distribution of coho salmon in the Bush Creek study area, 5 to 20 March 1981. Arrows originate at the center of each Section (Δ) and indicate the direction and average net movement of fish stocked in each Section.

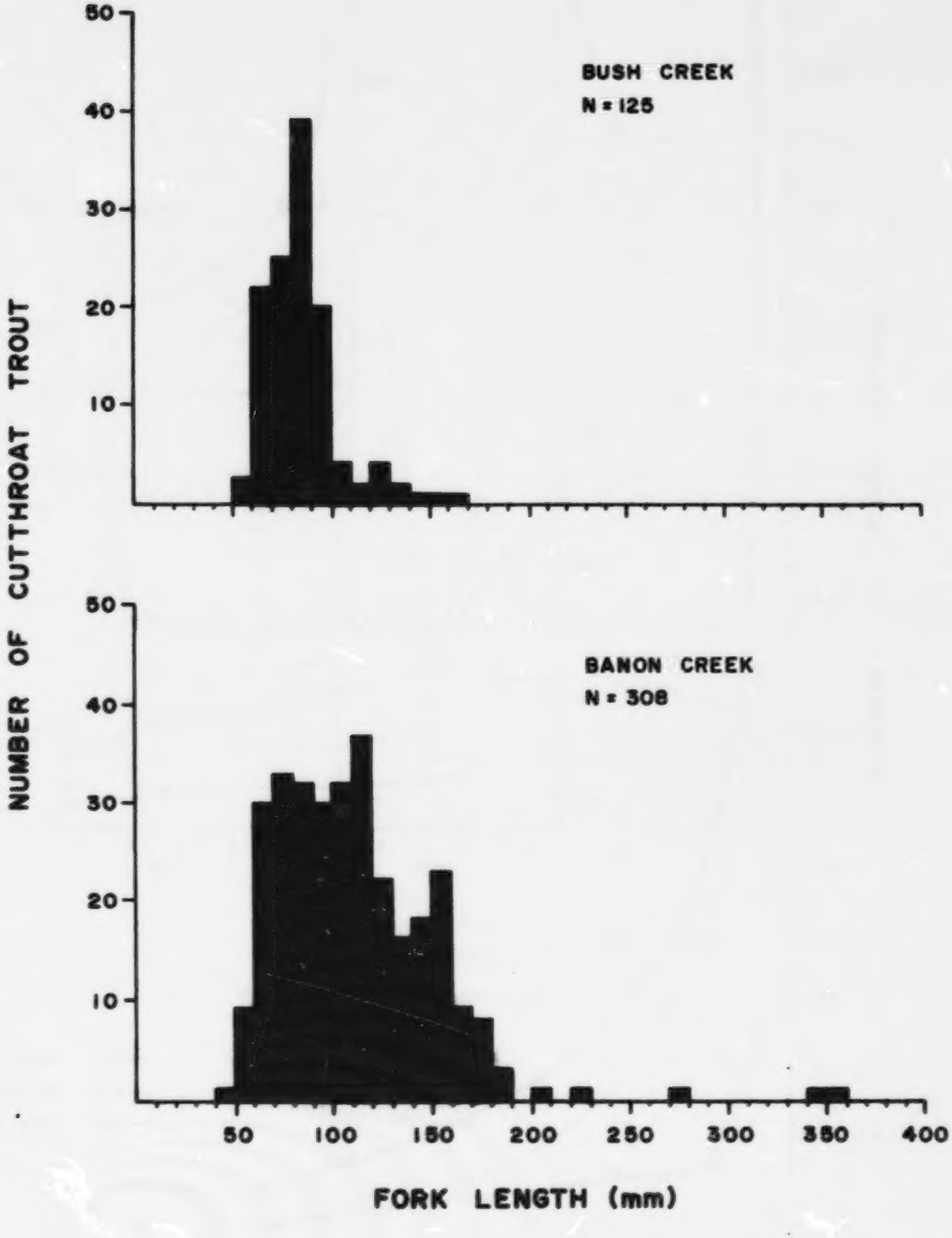

Figure 7. The length-frequency distributions of cutthroat trout captured moving downstream in Banon and Bush Creek, 9 March to 6 July 1981.

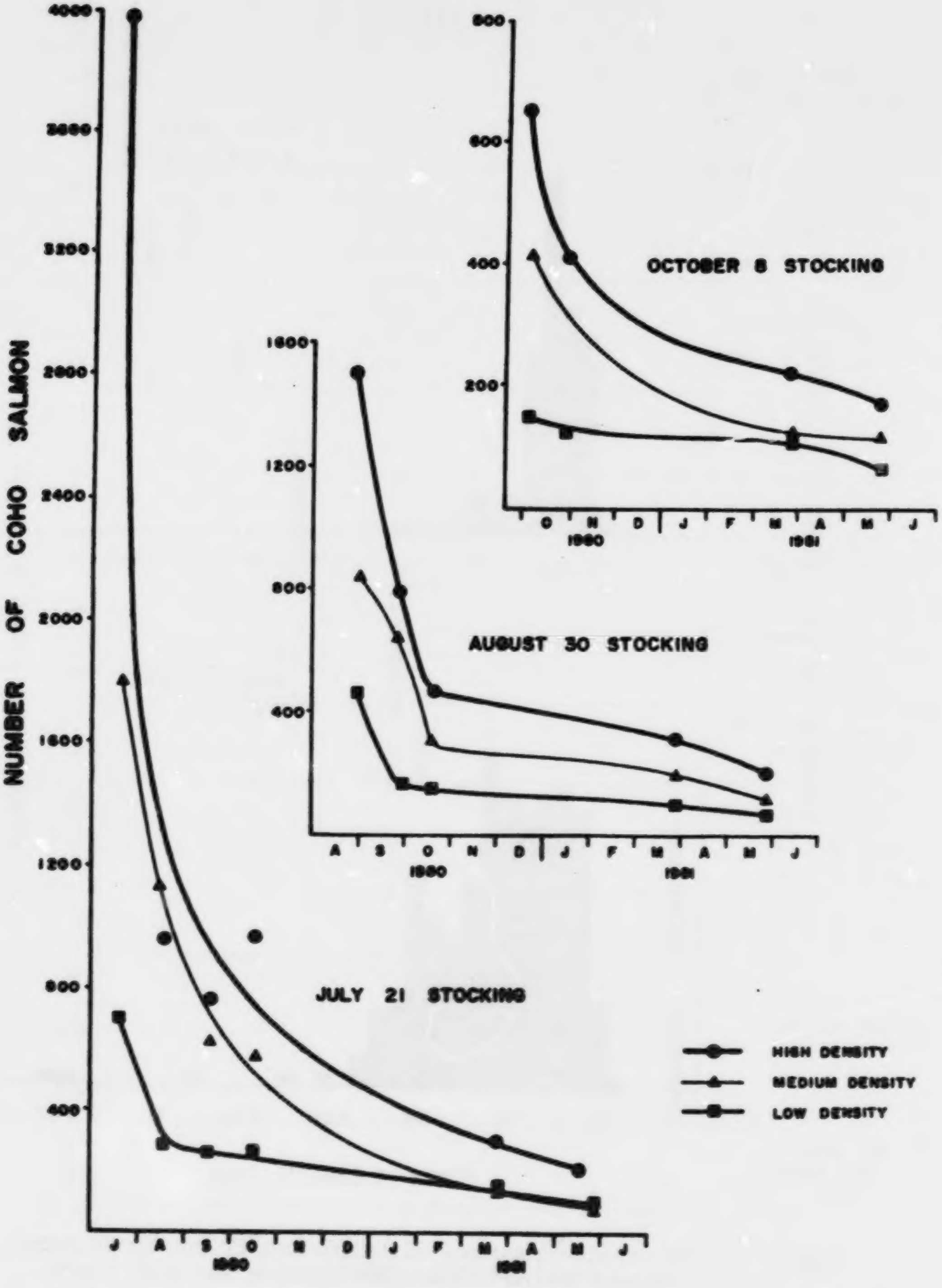

Figure 8. Coho population size in Sections stocked at different times and densities in Banon Creek.

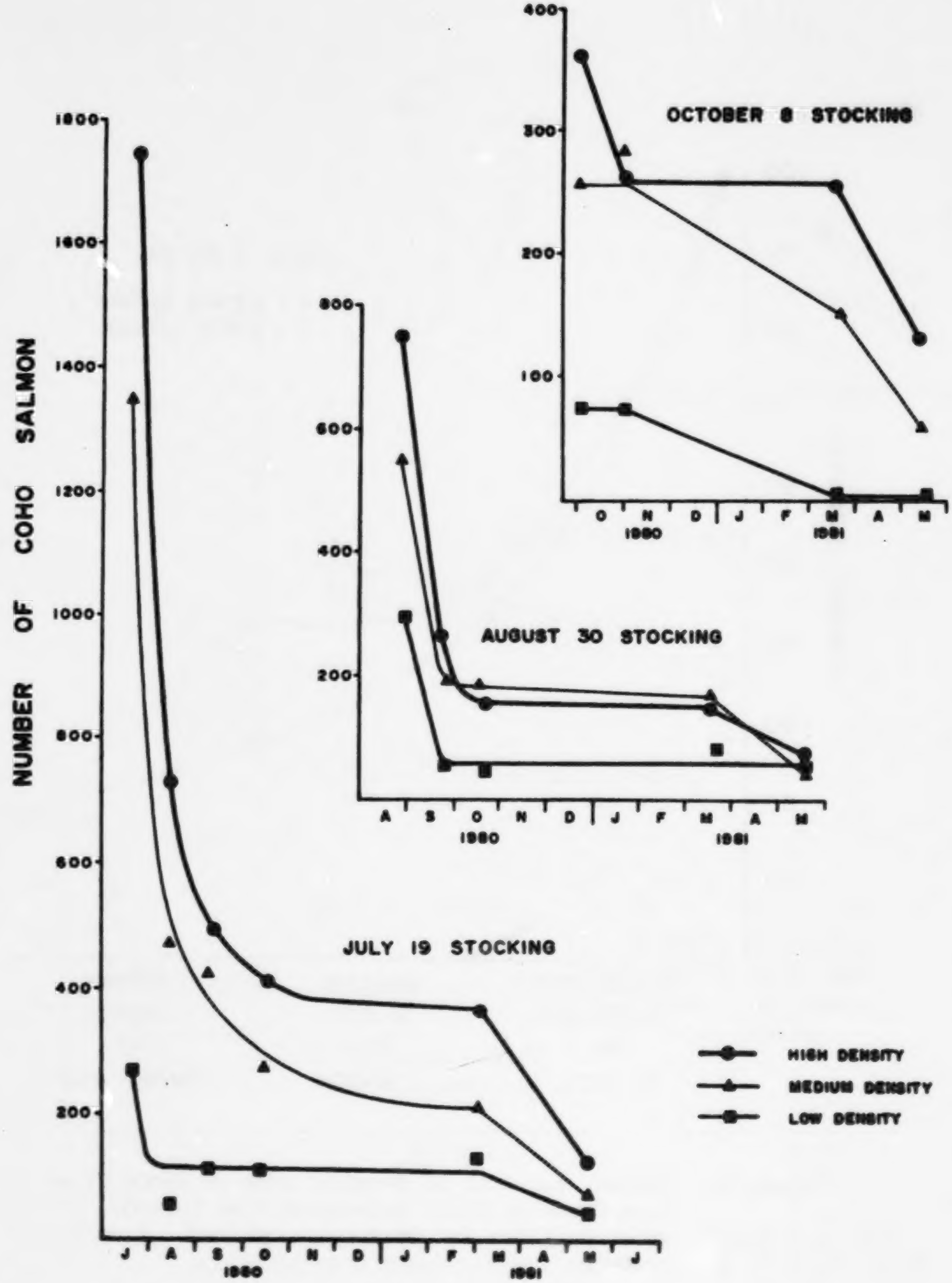

Figure 9. Coho population size in Sections stocked at different times and densities in Bush Creek.

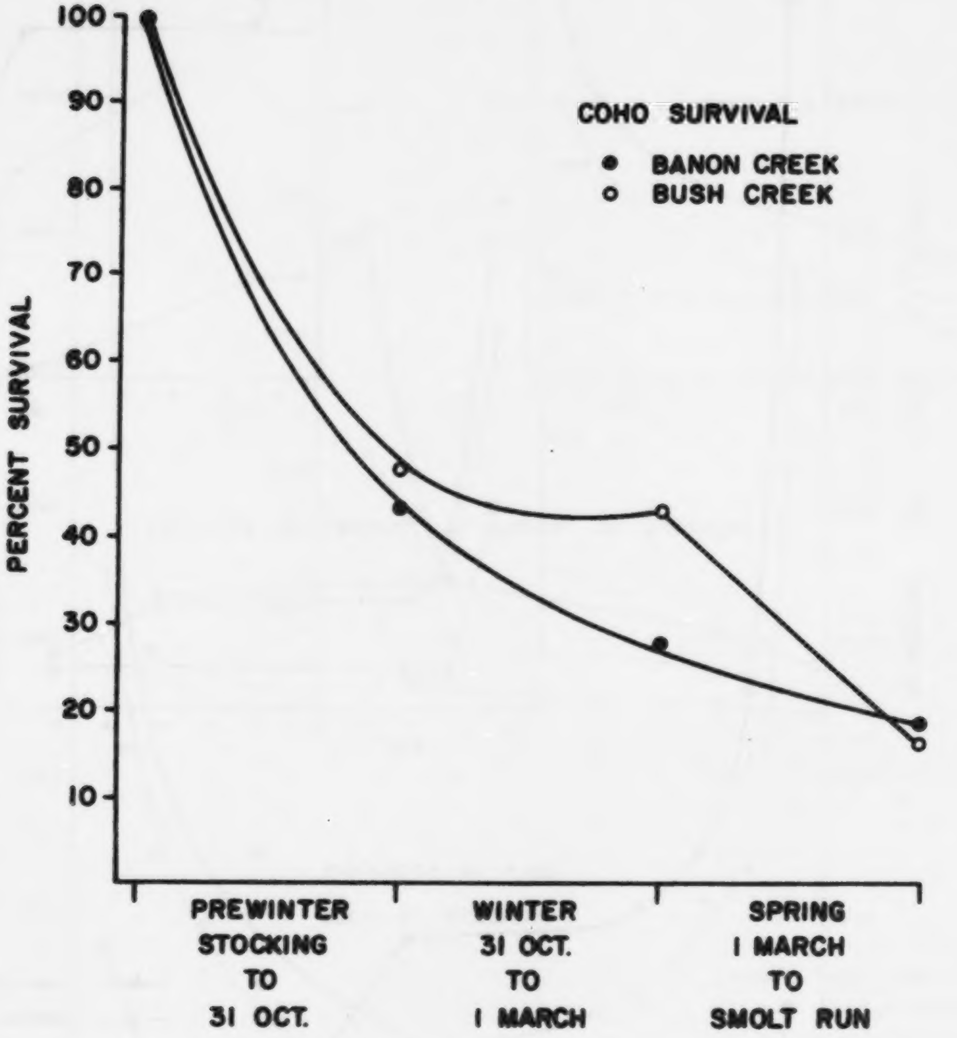

Figure 10. Overall survival of juvenile coho in Banon Creek and Bush Creek in three successive time periods, different stocking times and densities combined. Line fitted by eye.

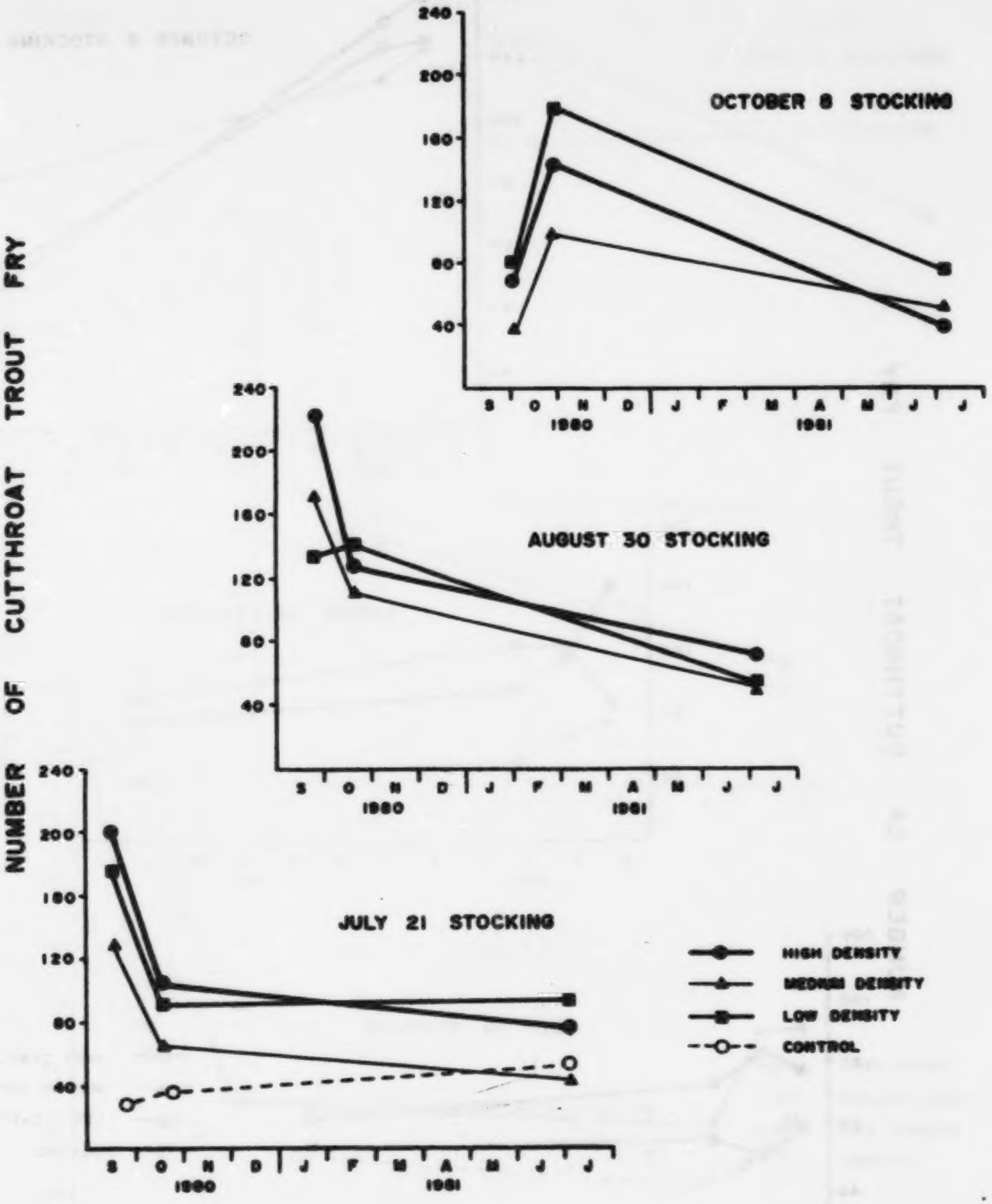

Figure 11. Cutthroat trout fry population size in Sections stocked with coho at different times and densities in Banon Creek.

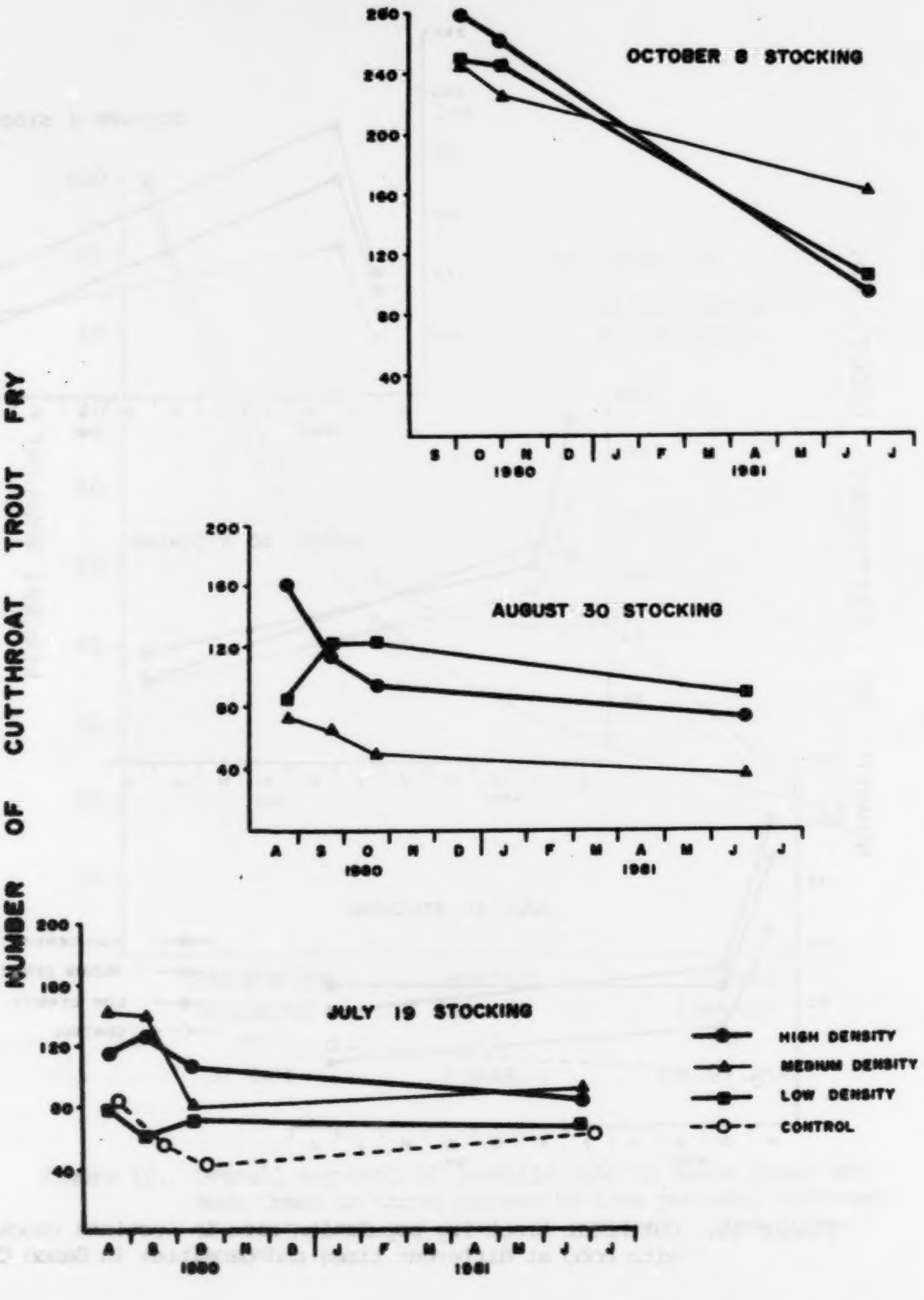

Figure 12. Cutthroat trout fry population size in Sections stocked with coho at different times and densities in Bush Creek.

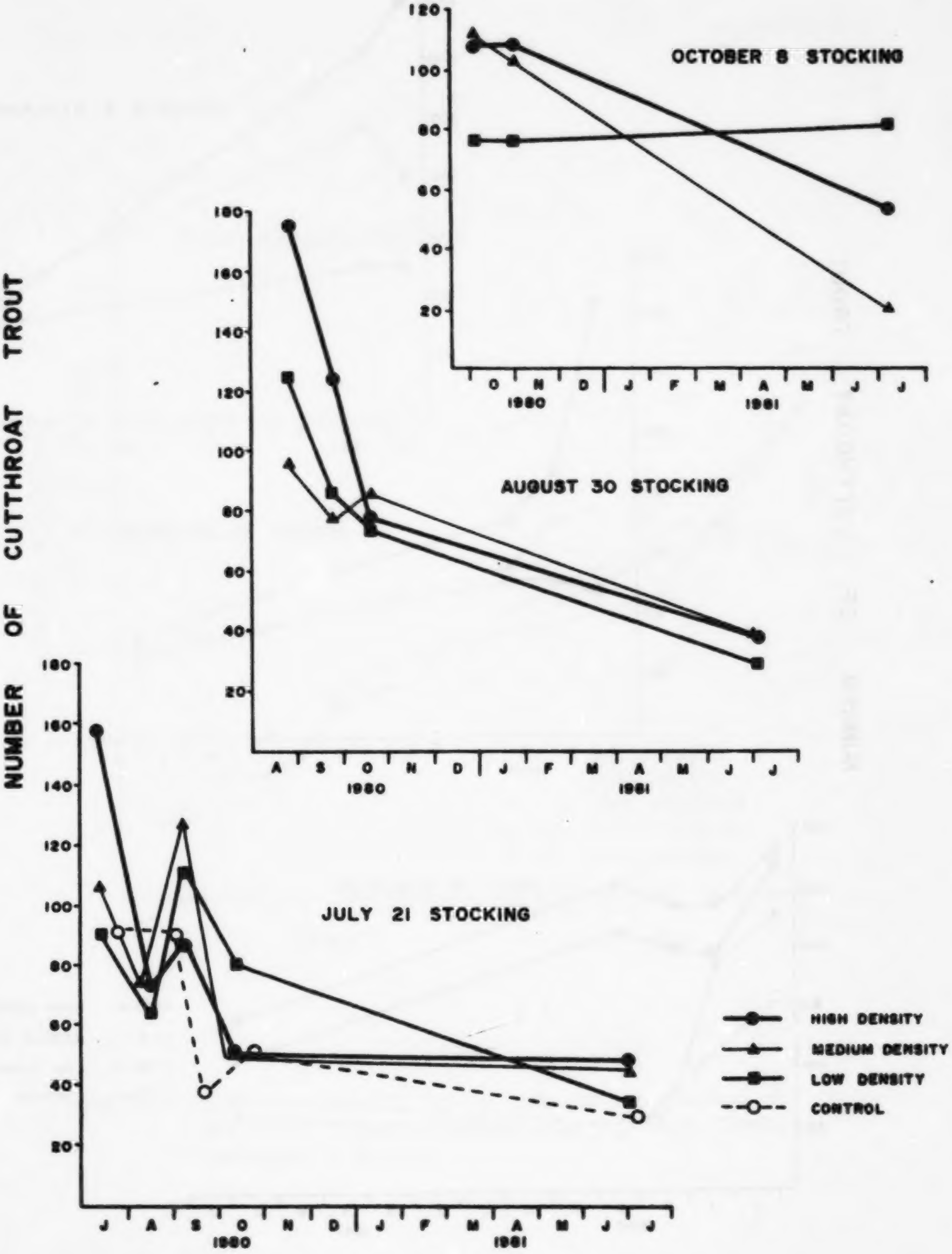

Figure 13. Older cutthroat trout population size in Sections stocked with coho at different times and densities in Banon Creek.

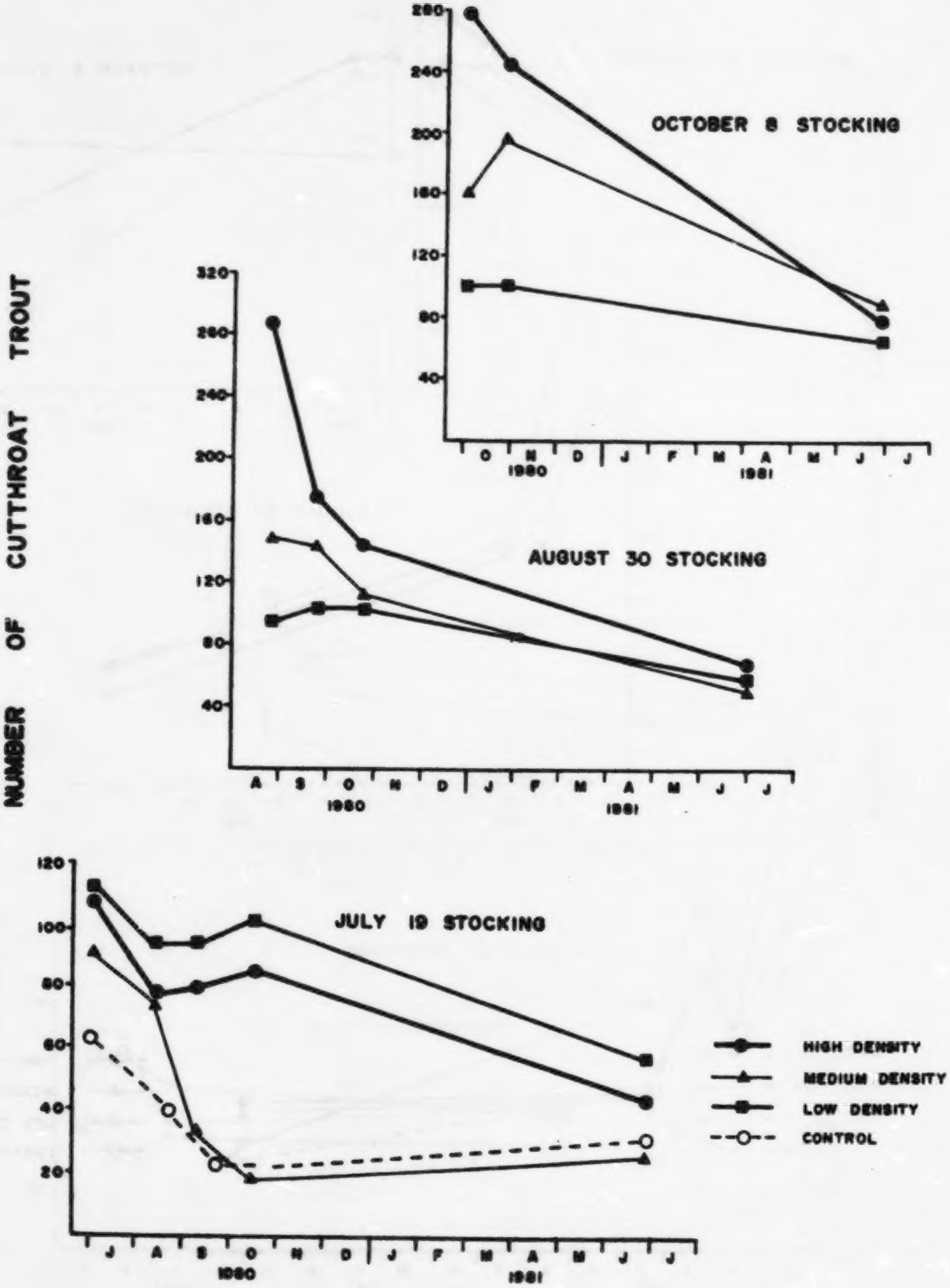

Figure 14. Older cutthroat trout population size in Sections stocked with coho at different times and densities in Bush Creek.

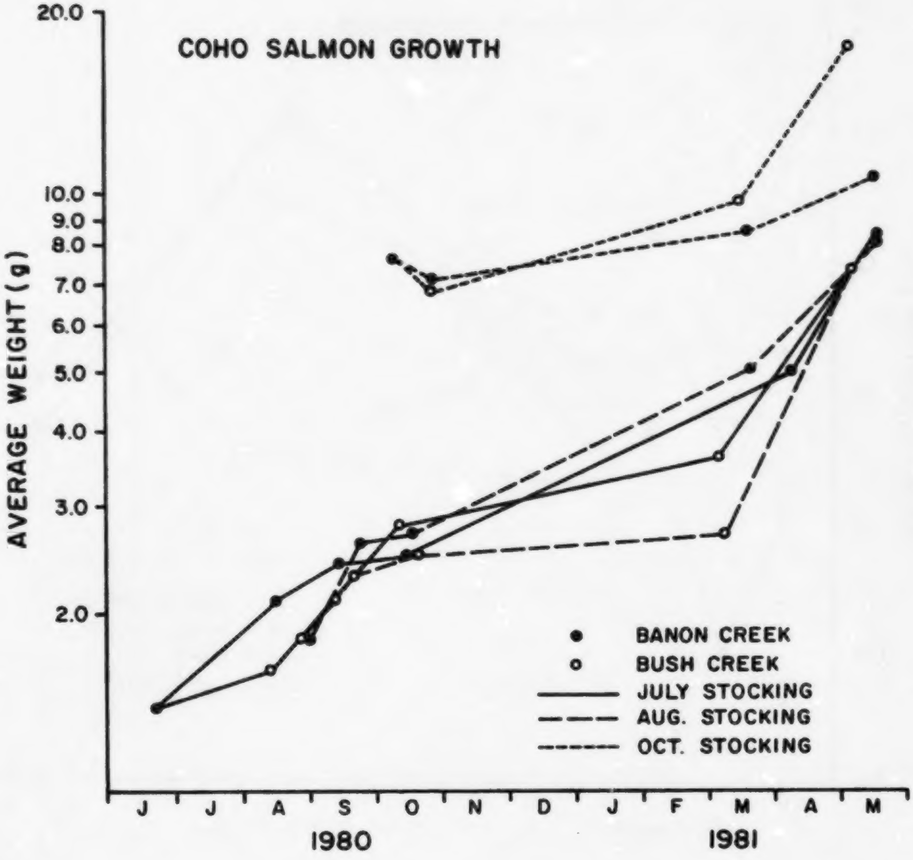

Figure 15. Growth in weight (g) by coho salmon shocked at different times in Banon Creek and Bush Creek, densities combined.

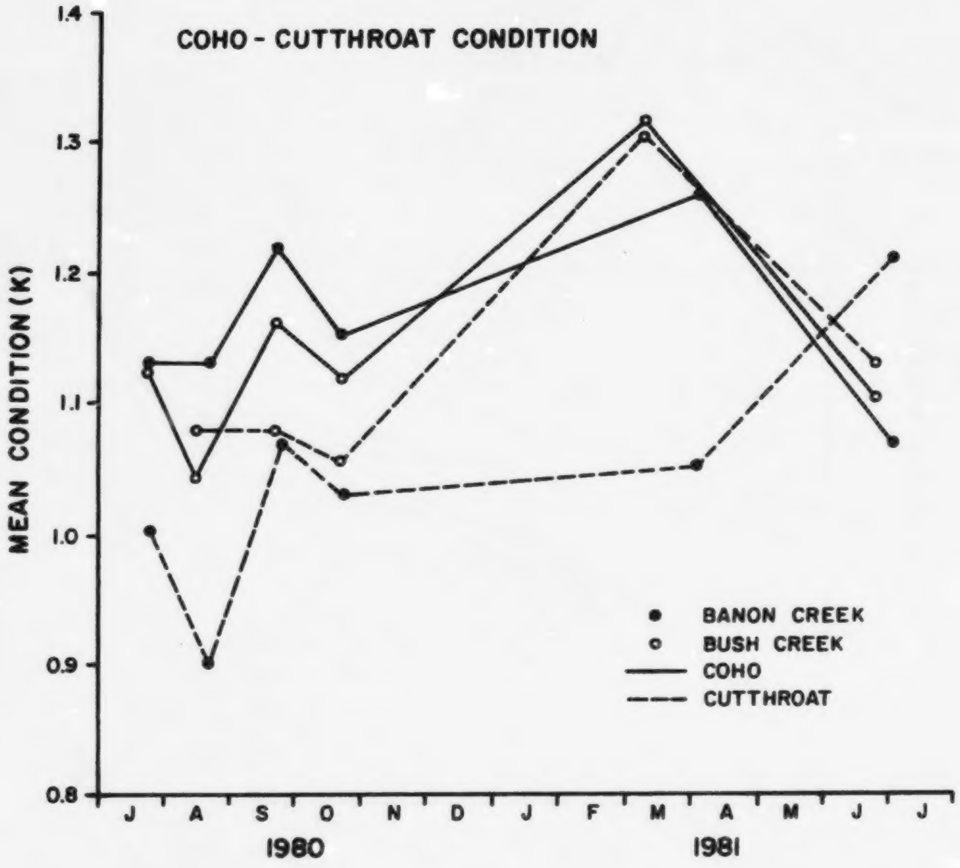

Figure 16. Seasonal variations in overall coho salmon and cutthroat trout fry condition (K) in Banon Creek and Bush Creek, experimental and control Sections combined.

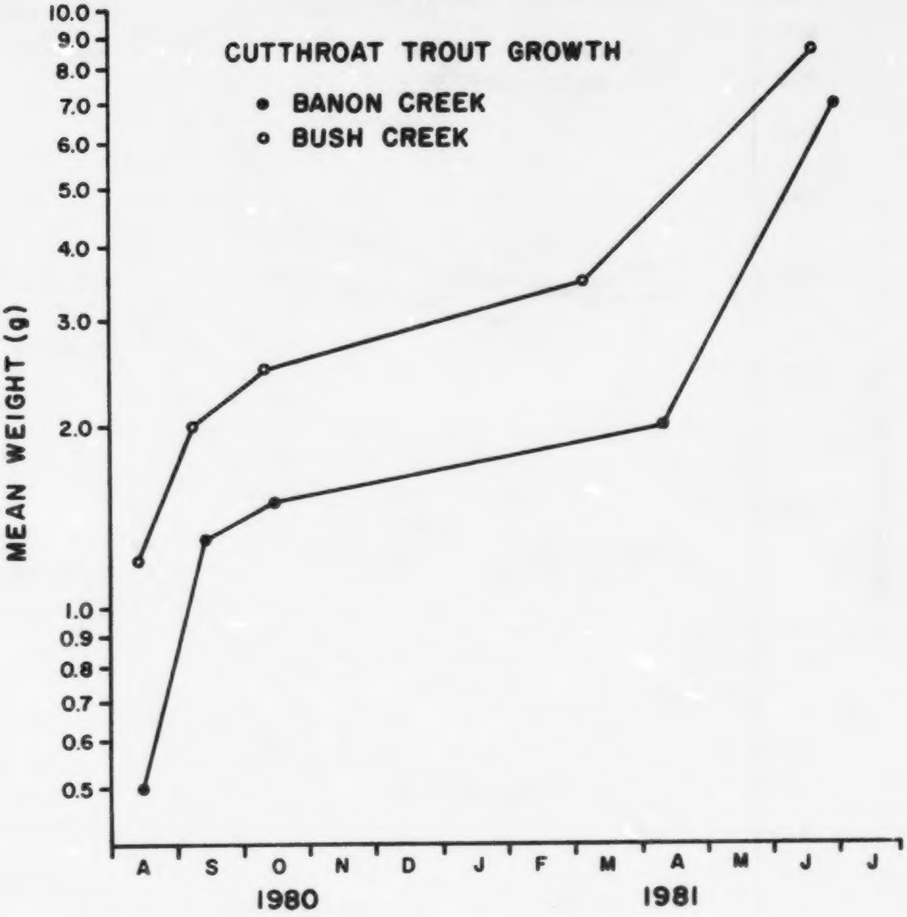

Figure 17. Overall growth in weight (g) by cutthroat trout fry in Banon Creek and Bush Creek, experimental and control Sections combined.

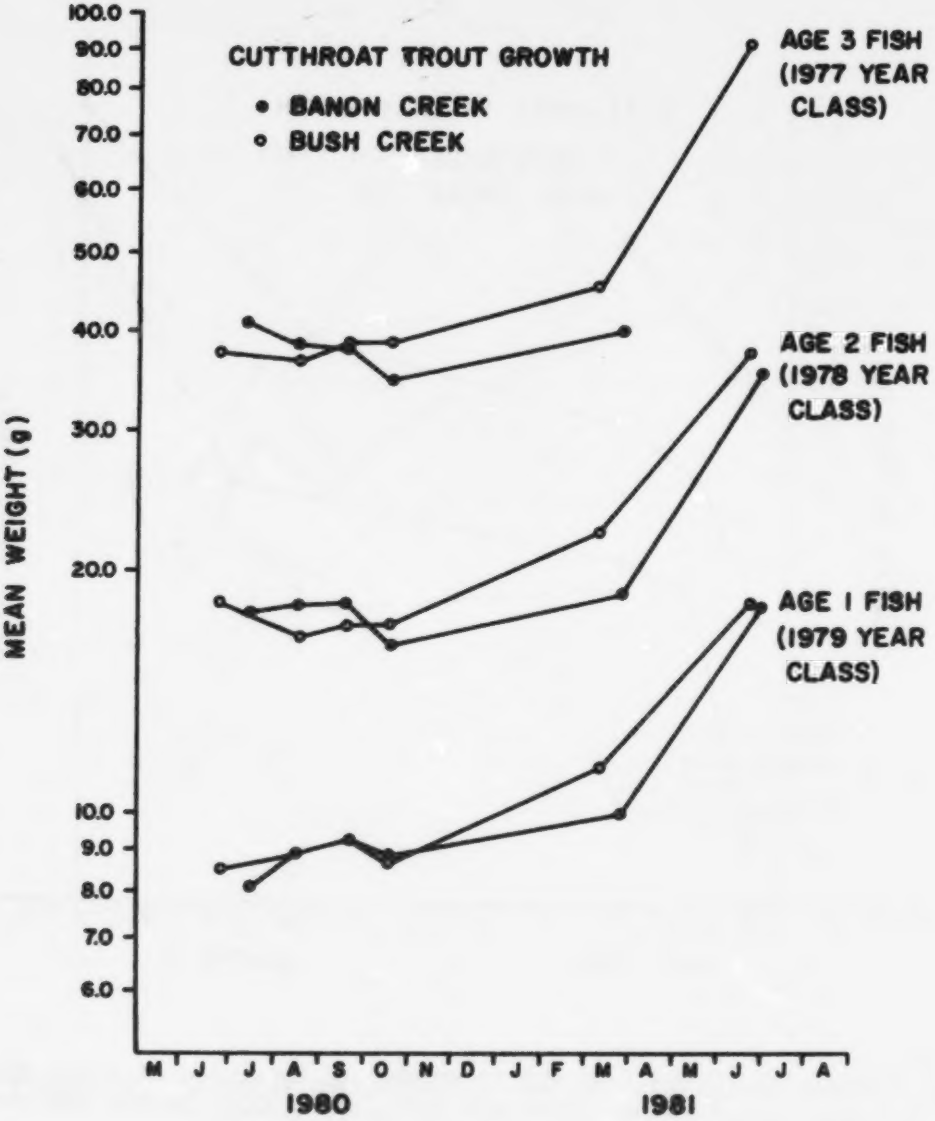

Figure 18. Growth in weight (g) by 1, 2, and 3 year old cutthroat trout in Banon Creek and Bush Creek, experimental and control Sections combined.

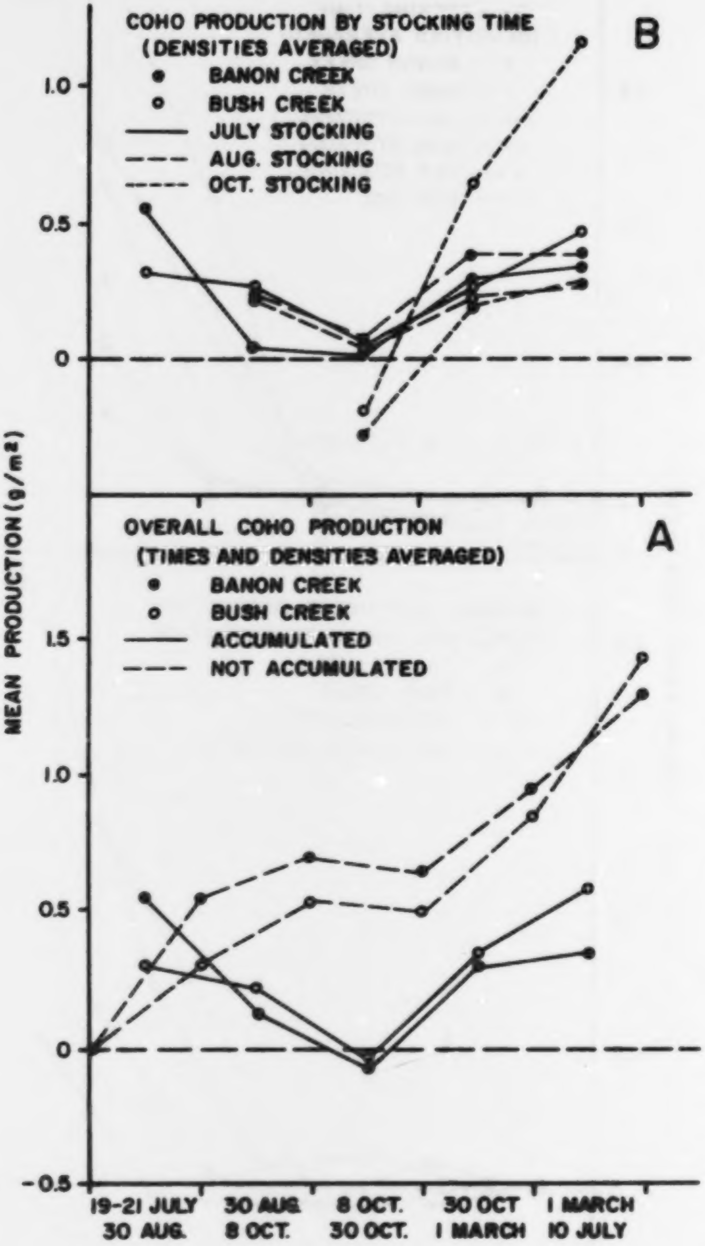

Figure 19. Coho salmon production in the Banon Creek and Bush Creek study areas, all Sections averaged (A), and Sections stocked at the same density averaged (B).

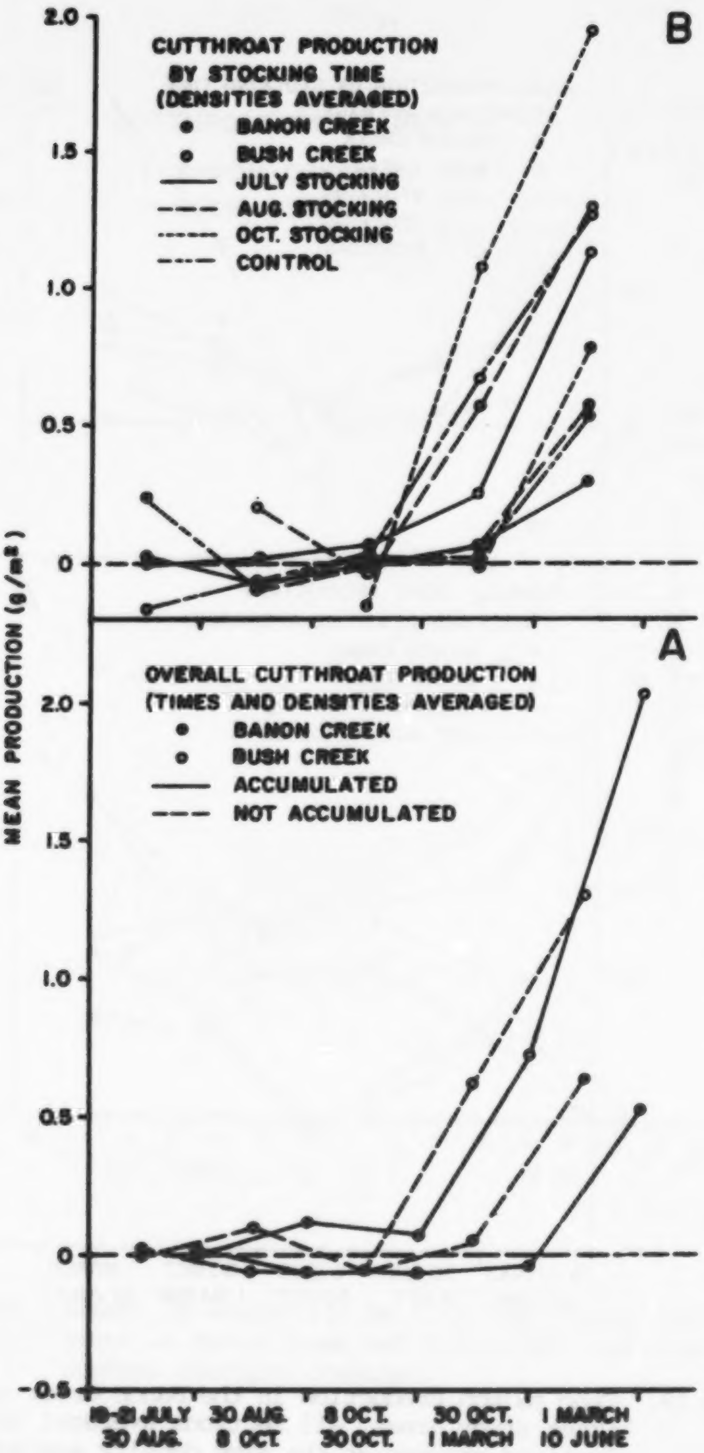

Figure 20. Cutthroat trout production in the Banon Creek and Bush Creek study areas, all Sections averaged (A), and Sections stocked with coho at the same density averaged (B).

APPENDIX

DATA FOR MEAN WEIGHTS, INSTANTAENOUS GROWTH RATES, DENSITY, BIOMASS, AND PRODUCTION

LIST OF TABLES

Table A1 Mean weights, instantaneous growth rates, density, biomass, and production of coho salmon in experimental Sections 1 to 9 of Banon Creek, 20 July 1980 to 10 June 1981.

Table A2 Mean weights, instantaneous growth rates, density, biomass, and production of coho salmon in experimental Sections 1 to 9 of Bush Creek, 20 July 1980 to 10 June 1981.

Table A3 Mean weights, instantaenous growth rates, density, biomass, and production of young-of-the-year cutthroat trout from the 1980 year class in Sections 1 to 10 of Banon Creek, 8 October 1980 to 10 June 1981.

Table A4 Mean weights, instantaneous growth rates, density, biomass, and production of young-of-the-year cutthroat trout from the 1980 year class in Sections 1 to 10 of Bush Creek, 8 October 1980 to 10 June 1981.

Table A5 Mean weights, instantaneous growth rates, density, biomass, and production of the 1976 to 1979 year classes of cutthroat trout in Sections 1 to 10 of Banon Creek, 20 July 1980 to 10 June 1981.

Table A6 Mean weights, instantaneous growth rates, density, biomass, and production of the 1976 to 1979 year classes of cutthroat trout in Sections 1 to 10 of Bush Creek, 20 July 1980 to 10 June 1981.

Table A1 Mean weights, instantaneous growth rates, density, biomass, and production of coho salmon in experimental Sections 1 to 9 of Banon Creek, 20 July 1980 to 10 June 1981.

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m²	Biomass (g/m²)	Mean Biomass (g/m²)	Production (g/m²)
1	20 July	1.4		1.72	2.41		
2324 m²	30 Aug	2.3	.496	0.47	1.08	1.75	0.87
	8 Oct	2.4	.043	0.34	0.82	0.95	0.04
	30 Oct	2.4	.000	0.29	0.70	0.76	0.00
	1 March	5.4	.811	0.14	0.76	0.73	0.59
	10 June	8.9	.500	0.09	0.80	0.78	0.39
2	20 July	1.4		0.91	1.27		
1987 m²	30 Aug	2.2	.452	0.44	0.97	1.12	0.51
	8 Oct	2.3	.044	0.28	0.64	0.81	0.04
	30 Oct	2.5	.083	0.21	0.53	0.59	0.05
	1 March	3.9	.445	0.08	0.31	0.42	0.19
	10 June	8.8	.814	0.05	0.44	0.37	0.30
3	20 July	1.4		0.48	0.67		
1473 m²	30 Aug	2.4	.539	0.19	0.46	0.57	0.31
	8 Oct	2.8	.154	0.17	0.48	0.47	0.07
	30 Oct	3.0	.069	0.16	0.48	0.48	0.03
	1 March	3.9	.262	0.10	0.39	0.43	0.11
	10 June	8.2	.743	0.06	0.49	0.44	0.33

Continued

Table A1 Continued

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m²	Biomass (g/m²)	Mean Biomass (g/m²)	Production (g/m²)
4	30 Aug	1.8		1.02	1.84		
1477 m²	8 Oct	2.6	.368	0.41	1.07	1.46	0.54
	30 Oct	2.8	.074	0.30	0.84	0.96	0.07
	1 March	4.5	.474	0.24	1.08	0.96	0.46
	10 June	7.5	.511	0.11	0.83	0.96	0.49
5	30 Aug	1.8		0.84	1.51		
1014 m²	8 Oct	2.5	.329	0.45	1.13	1.32	0.43
	30 Oct	3.0	.182	0.28	0.84	0.99	0.18
	1 March	5.4	.588	0.22	1.19	1.01	0.59
	10 June	8.3	.430	0.12	1.00	1.09	0.47
6	30 Aug	1.8		0.26	0.47		
1804 m²	8 Oct	2.9	.477	0.09	0.26	0.37	0.18
	30 Oct	3.1	.067	0.08	0.25	0.25	0.02
	1 March	4.7	.416	0.07	0.33	0.29	0.12
	10 June	8.9	.638	0.04	0.36	0.35	0.22
7							
1062 m²	8 Oct	7.8		0.61	4.76		
	30 Oct	6.7	-.152	0.38	2.55	3.66	-0.56
	1 March	7.9	.164	0.22	1.74	2.15	0.35
	10 June	10.4	.275	0.16	1.66	1.70	0.47

Continued

Table A1 Concluded

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
8	8 Oct	7.8		0.33	2.57		
1240 m^2	30 Oct	7.0	-.108	0.24	1.68	2.13	-0.23
	1 March	7.3	.042	0.10	0.73	1.21	0.05
	10 June	10.6	.373	0.09	0.95	0.84	0.31
9	8 Oct	7.8		0.09	0.70		
1584 m^2	30 Oct	7.3	-.066	0.08	0.58	0.64	-0.04
	1 March	9.9	.304	0.07	0.69	0.63	0.19
	10 June	10.9	.096	0.04	0.44	0.57	0.05

Table A2 Mean weights, instantaneous growth rates, density, biomass, and production of coho salmon in experimental Sections 1 to 9 of Bush Creek, 20 July 1980 to 10 June 1981.

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m²	Biomass (g/m²)	Mean Biomass (g/m²)	Production (g/m²)
1 1060 m²	20 July	1.4		1.65	2.31		
	30 Aug	1.8	.251	0.49	0.88	1.59	0.40
	8 Oct	2.7	.405	0.39	1.05	0.97	0.39
	30 Oct	2.9	.071	0.37	1.07	1.06	0.07
	1 March	3.7	.244	0.35	1.30	1.19	0.29
	10 June	7.5	.707	0.11	0.83	1.07	0.76
2 779 m²	26 July	1.4		1.73	2.42		
	30 Aug	1.7	.194	0.51	0.87	1.64	0.32
	8 Oct	2.3	.302	0.39	0.90	0.89	0.27
	30 Oct	2.6	.123	0.35	0.91	0.91	0.11
	1 March	3.8	.379	0.27	1.03	0.97	0.37
	10 June	7.0	.611	0.09	0.63	1.33	0.28
3 705 m²	20 July	1.4		0.39	0.55		
	30 Aug	2.2	.452	0.16	0.35	0.45	0.20
	8 Oct	3.0	.310	0.16	0.48	0.41	0.13
	30 Oct	3.2	.065	0.16	0.51	0.49	0.03
	1 March	4.1	.248	0.16	0.66	0.59	0.15
	10 June	8.0	.668	0.07	0.56	0.61	0.41

Continued

Table A2 Continued

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m²	Biomass (g/m²)	Mean Biomass (g/m²)	Production (g/m²)
4	30 Aug	1.8		0.91	1.64		
824 m²	8 Oct	2.3	.245	0.21	0.48	1.06	0.26
	30 Oct	2.5	.083	0.19	0.47	0.47	0.04
	1 March	3.9	.447	0.18	0.70	0.59	0.26
	10 June	6.9	.556	0.08	0.60	0.65	0.36
5	30 Aug	1.8		0.67	1.21		
817 m²	8 Oct	2.5	.329	0.23	0.57	0.89	0.29
	30 Oct	2.8	.113	0.22	0.62	0.59	0.07
	1 March	4.2	.405	0.21	0.88	0.75	0.30
	10 June	7.7	.606	0.06	0.46	0.67	0.41
6	30 Aug	1.8		0.24	0.43		
1272 m²	8 Oct	2.5	.329	0.05	0.13	0.28	0.09
	30 Oct	2.7	.077	0.05	0.13	0.13	0.01
	1 March	5.5	.711	0.05	0.27	0.20	0.14
	10 June	7.7	.336	0.04	0.31	0.29	0.10
7	8 Oct	7.8		0.42	3.28		
860 m²	30 Oct	6.8	-.137	0.30	2.04	2.66	-0.36
	1 March	9.1	.291	0.30	2.73	2.29	0.70
	10 June	14.7	.480	0.15	2.21	2.47	1.18

Continued

Table A2 Concluded

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
8	8 Oct	7.8		0.29	2.26		
900 m^2	30 Oct	7.0	-.108	0.28	1.96	2.11	-0.23
	1 March	9.6	.316	0.19	1.82	1.89	0.60
	10 June	19.8	.724	0.07	1.39	1.61	1.17
9	8 Oct	7.8		0.08	0.62		
900 m^2	30 Oct	7.0	-.108	0.08	0.49	0.55	-0.06
	1 March	9.6	.316	0.004	0.04	0.27	0.09
	10 June	18.2	.602	0.004	0.07	0.05	0.03

Table A3 Mean weights, instantaneous growth rates, density, biomass, and production of young-of-the-year cutthroat trout from the 1980 year class in Sections 1 to 10 of Banon Creek, 8 October 1980 to 10 June 1981.

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m²	Biomass (g/m²)	Mean Biomass (g/m²)	Production (g/m²)
1	8 Oct	1.5		0.06	0.09		
2324 m²	30 Oct	1.6	.065	0.04	0.06	0.07	0.005
	1 March	1.8	.118	0.04	0.07	0.07	0.008
	10 June	5.0	1.002	0.03	0.15	0.11	0.112
2	8 Oct	1.2		0.04	0.04		
1987 m²	30 Oct	1.3	.080	0.03	0.04	0.04	0.003
	1 March	1.7	.268	0.03	0.05	0.05	0.013
	10 June	6.0	1.261	0.02	0.12	0.09	0.113
3	8 Oct	1.7		0.07	0.12		
1768 m²	30 Oct	1.7	.000	0.05	0.09	0.11	0.000
	1 March	2.1	.211	0.05	0.11	0.10	0.021
	10 June	6.0	1.050	0.05	0.30	0.21	0.221
4	8 Oct	1.7		0.12	0.20		
1477 m²	30 Oct	1.7	.000	0.09	0.15	0.17	0.000
	1 March	2.1	.211	0.07	0.15	0.15	0.032
	10 June	6.2	1.083	0.05	0.31	0.23	0.25

Continued

Table A3 Continued

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m²	Biomass (g/m²)	Mean Biomass (g/m²)	Production (g/m²)
5	8 Oct	1.7		0.13	0.22		
1014 m²	30 Oct	1.9	.111	0.11	0.21	0.21	0.02
	1 March	2.0	.051	0.08	0.16	0.19	0.01
	10 June	6.4	1.163	0.06	0.38	0.27	0.31
6	8 Oct	2.2		0.08	0.18		
1804 m²	30 Oct	2.1	-.047	0.08	0.17	0.17	-0.01
	1 March	1.9	-.100	0.05	0.09	0.13	-0.01
	10 June	6.2	1.183	0.03	0.19	0.14	0.17
7	8 Oct	1.7		0.08	0.14		
1062 m²	30 Oct	1.9	.111	0.13	0.25	0.19	0.02
	1 March	1.8	.054	0.09	0.16	0.21	0.01
	10 June	5.3	1.080	0.05	0.27	0.21	0.23
8	8 Oct	2.2		0.04	0.09		
1240 m²	30 Oct	2.5	.128	0.08	0.20	0.15	0.02
	1 March	2.5	.000	0.06	0.15	0.17	0.00
	10 June	6.7	.986	0.05	0.33	0.24	0.24
9	8 Oct	2.0		0.07	0.14		
1584 m²	30 Oct	2.3	.140	0.11	0.25	0.19	0.03
	1 March	2.5	0.83	0.08	0.20	0.23	0.02
	10 June	6.3	.924	0.05	0.31	0.25	0.23

Continued

Table A3 Concluded

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m²	Biomass (g/m²)	Mean Biomass (g/m²)	Production (g/m²)
Control 996 m²	8 Oct	1.8		0.03	0.05		
	30 Oct	2.3	.245	0.04	0.09	0.07	0.02
	1 March	2.1	-.091	0.04	0.08	0.09	-0.01
	10 June	5.8	1.016	0.05	0.29	0.19	0.19

Table A4 Mean weights, instantaneous growth rates, density, biomass, and production of young-of-the-year cutthroat trout from the 1980 year class in Sections 1 to 10 of Bush Creek, 8 October 1980 to 10 June 1981.

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m²	Biomass (g/m²)	Mean Biomass (g/m²)	Production (g/m²)
1	8 Oct	2.5		0.10	0.25		
1060 m²	30 Oct	2.7	.077	0.10	0.27	0.26	0.02
	1 March	3.3	.201	0.09	0.30	0.29	0.06
	10 June	8.1	.898	0.08	0.65	0.47	0.42
2	8 Oct	2.4		0.11	0.26		
779 m²	30 Oct	2.6	.080	0.10	0.26	0.26	0.02
	1 March	3.7	.353	0.11	0.41	0.33	0.12
	10 June	8.0	.771	0.12	0.96	0.69	0.53
3	8 Oct	2.5		0.10	0.25		
705 m²	30 Oct	2.7	.077	0.10	0.27	0.26	0.02
	1 March	3.3	.201	0.10	0.33	0.30	0.06
	10 June	7.9	.873	0.09	0.71	0.52	0.45
4	8 Oct	2.3		0.13	0.30		
824 m²	30 Oct	2.3	.000	0.11	0.25	0.23	0.00
	1 March	2.8	.197	0.10	0.28	0.27	0.05
	10 June	7.9	1.037	0.09	0.71	0.49	0.51

Continued

Table A4 Continued

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
5	8 Oct	2.7		0.07	0.19		
817 m^2	30 Oct	2.8	.036	0.06	0.17	0.18	0.01
	1 March	3.8	.305	0.05	0.19	0.18	0.05
	10 June	8.3	.781	0.05	0.41	0.30	0.23
6	8 Oct	2.6		0.10	0.26		
1272 m^2	30 Oct	2.8	.074	0.10	0.26	0.26	0.02
	1 March	4.0	.357	0.08	0.32	0.29	0.10
	10 June	8.5	.754	0.07	0.59	0.45	0.34
7	8 Oct	2.3		0.32	0.74		
860 m^2	30 Oct	2.5	.083	0.31	0.77	0.75	0.06
	1 March	3.4	.307	0.21	0.71	0.74	0.23
	10 June	7.9	.843	0.13	1.03	0.87	0.73
8	8 Oct	2.7		0.27	0.73		
900 m^2	30 Oct	2.7	.000	0.25	0.67	0.70	0.00
	1 March	4.8	.575	0.21	1.01	0.84	0.48
	10 June	8.2	.536	0.19	1.56	1.29	0.69

Continued

Table A4 Concluded

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
9 792 m^2	8 Oct	2.7		0.31	0.84		
	30 Oct	2.7	.000	0.31	0.84	0.84	0.00
	1 March	3.7	.315	0.22	0.81	0.83	0.26
	10 June	8.5	.832	0.15	1.27	1.04	0.87
Control 408 m^2	8 Oct	1.8		0.12	0.22		
	30 Oct	1.9	.054	0.10	0.19	0.21	0.01
	1 March	4.0	.744	0.13	0.52	0.71	0.53
	10 June	8.7	.777	0.15	1.31	0.91	0.71

Table A5 Mean weights, instantaneous growth rates, density, biomass, and production of the 1976 to 1979 year classes of cutthroat trout in Sections 1 to 10 of Banon Creek, 20 July 1980 to 10 June 1981.

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
1	20 July	9.8		0.057	0.56		
2324 m^2	30 Aug	10.6	−0.03	0.032	0.35	0.45	−0.01
	8 Oct	10.6	−0.10	0.025	0.27	0.31	−0.03
	30 Oct	10.7	−0.02	0.021	0.23	0.25	−0.01
	1 March	11.4	0.21	0.021	0.24	0.23	0.05
	10 June	17.8	0.46	0.021	0.37	0.31	0.14
2	20 July	15.2		0.049	0.75		
1987 m^2	30 Aug	15.6	0.01	0.051	0.79	0.77	0.01
	8 Oct	13.3	−0.16	0.034	0.46	0.63	−0.10
	30 Oct	12.9	−0.02	0.025	0.32	0.39	−0.01
	1 March	13.7	0.19	0.024	0.32	0.32	0.06
	10 June	19.1	0.46	0.023	0.43	0.37	0.17
3	20 July	13.5		0.048	0.64		
1768 m^2	30 Aug	14.5	0.03	0.050	0.72	0.68	0.02
	8 Oct	13.4	−0.07	0.050	0.67	0.69	−0.04
	30 Oct	13.2	0.00	0.044	0.58	0.63	0.00
	1 March	14.1	0.17	0.031	0.43	0.51	0.09
	10 June	17.8	0.40	0.021	0.37	0.40	0.16

Continued

Table A5 Continued

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
4	30 Aug	18.1		0.112	2.03		
1477 m^2	8 Oct	16.3	−0.05	0.064	1.05	1.54	−0.08
	30 Oct	15.3	0.00	0.051	0.79	0.91	0.00
	1 March	13.3	0.02	0.037	0.50	0.65	0.01
	10 June	19.4	0.63	0.028	0.55	0.53	0.33
5	30 Aug	14.0		0.092	1.28		
1014 m^2	8 Oct	15.0	−0.13	0.082	1.23	1.25	−0.16
	30 Oct	15.7	−0.03	0.084	1.32	1.27	−0.04
	1 March	14.9	0.11	0.060	0.90	1.11	0.12
	10 June	18.1	0.57	0.043	0.79	0.85	0.48
6	30 Aug	18.3		0.065	1.19		
1804 m^2	8 Oct	14.8	−0.04	0.043	0.64	0.91	−0.04
	30 Oct	12.4	−0.03	0.039	0.49	0.57	−0.02
	1 March	13.2	0.03	0.028	0.37	0.43	0.01
	10 June	19.9	0.54	0.018	0.36	0.37	0.20
7	8 Oct	14.3		0.102	1.45		
1062 m^2	30 Oct	12.4	−0.02	0.102	1.26	1.35	−0.03
	1 March	13.3	0.14	0.076	1.01	1.13	0.16
	10 June	22.6	0.60	0.056	1.26	1.13	0.68

Continued

Table A5 Concluded

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
8	8 Oct	16.6		0.099	1.65		
1240 m^2	30 Oct	14.7	-0.03	0.131	1.92	1.79	-0.05
	1 March	15.3	0.06	0.076	1.16	1.54	0.09
	10 June	25.7	0.59	0.029	0.75	0.95	0.56
9	8 Oct	13.2		0.049	0.64		
1584 m^2	30 Oct	13.5	0.02	0.049	0.66	0.65	0.01
	1 March	12.3	0.04	0.050	0.61	0.63	0.03
	10 June	17.3	0.54	0.051	0.87	0.74	0.40
10	20 July	15.5		0.092	1.43		
996 m^2	30 Aug	17.1	0.16	0.90	1.55	1.49	0.23
	8 Oct	15.4	-0.06	0.044	0.68	1.11	-0.07
	30 Oct	16.3	0.03	0.049	0.80	0.74	0.02
	1 March	14.5	0.01	0.040	0.58	0.69	0.01
	10 June	20.6	0.56	0.033	0.68	0.63	0.35

Table A6 Mean weights, instantaneous growth rates, density, biomass, and production of the 1976 to 1979 year classes of cutthroat trout in Sections 1 to 10 of Bush Creek, 20 July 1980 to 10 June 1981.

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
1	20 July	16.2		.087	1.41		
1060 m^2	30 Aug	15.3	-0.09	.073	1.11	1.26	-0.11
	8 Oct	15.1	0.02	.079	1.20	1.15	0.02
	30 Oct	15.6	0.04	.077	1.21	1.21	0.05
	1 March	17.9	0.19	.060	1.08	1.15	0.22
	10 June	26.7	0.52	.044	1.18	1.13	0.59
2	20 July	14.2		.107	1.51		
779 m^2	30 Aug	12.5	0.05	.059	0.74	1.13	0.06
	8 Oct	14.5	0.04	.026	0.37	0.55	0.02
	20 Oct	15.6	0.03	.024	0.38	0.37	0.01
	1 March	16.0	0.17	.030	0.47	0.43	0.07
	10 June	20.2	0.44	.035	0.70	0.59	0.26
3	20 July	14.1		.148	2.08		
705 m^2	30 Aug	14.9	0.03	.133	1.99	2.03	0.06
	8 Oct	15.1	0.02	.142	2.14	2.07	0.04
	30 Oct	15.3	0.06	.139	2.13	2.13	0.13
	1 March	16.5	0.12	.111	1.82	1.97	0.24
	10 June	25.2	0.55	.087	2.18	2.00	1.10

Continued

Table A6 Continued

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
4	30 Aug	12.1		.316	3.82		
824 m^2	8 Oct	13.9	0.07	.187	2.60	3.21	0.22
	30 Oct	14.8	−0.04	.166	2.46	2.53	−0.10
	1 March	17.2	0.30	.125	2.15	2.31	0.69
	10 June	23.6	0.55	.089	2.09	2.12	1.17
5	30 Aug	17.1		.180	3.08		
817 m^2	8 Oct	19.0	0.08	.153	2.91	3.00	0.24
	30 Oct	19.4	−0.03	.132	2.56	2.73	−0.08
	1 March	21.2	0.22	.099	2.10	2.33	0.51
	10 June	26.5	0.48	.071	1.88	1.99	0.95
6	30 Aug	16.2		.074	1.20		
1272 m^2	8 Oct	19.8	0.09	.080	1.59	1.39	0.13
	30 Oct	22.0	0.04	.080	1.76	1.67	0.07
	1 March	23.6	0.19	.062	1.47	1.61	0.31
	10 June	30.4	0.48	.047	1.43	1.45	0.70
7	8 Oct	17.4		.313	5.44		
860 m^2	30 Oct	15.4	−0.11	.284	4.37	4.91	−0.54
	1 March	19.5	0.28	.185	3.61	3.99	1.12
	10 June	28.1	0.47	.101	2.84	3.23	1.52

Continued

Table A6 Concluded

Section No.	Date	Mean Weight (g)	Growth Rate (G)	No/m^2	Biomass (g/m^2)	Mean Biomass (g/m^2)	Production (g/m^2)
8	8 Oct	18.1		.187	3.38		
900 m^2	30 Oct	18.7	0.00	.214	4.01	3.69	0.00
	1 March	20.7	0.22	.158	3.27	3.64	0.80
	10 June	26.9	0.45	.108	2.90	3.09	1.39
9	8 Oct	12.9		.117	1.51		
792 m^2	30 Oct	13.3	0.01	.126	1.68	1.59	0.02
	1 March	15.9	0.23	.105	1.67	1.67	0.38
	10 June	20.1	0.40	.085	1.70	1.69	0.68
10	20 July	12.0		.127	1.53		
408 m^2	30 Aug	12.1	−0.13	.088	1.07	1.30	−0.17
	8 Oct	15.4	0.06	.051	0.79	0.93	0.06
	30 Oct	15.7	0.02	.049	0.77	0.78	0.02
	1 March	14.9	0.17	.064	0.95	0.86	0.15
	10 June	20.1	0.45	.078	1.58	1.27	0.57